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Resources Canada

Énergie, Mines et
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CANMET

Canada Centre for
Mineral and Energy
Technology

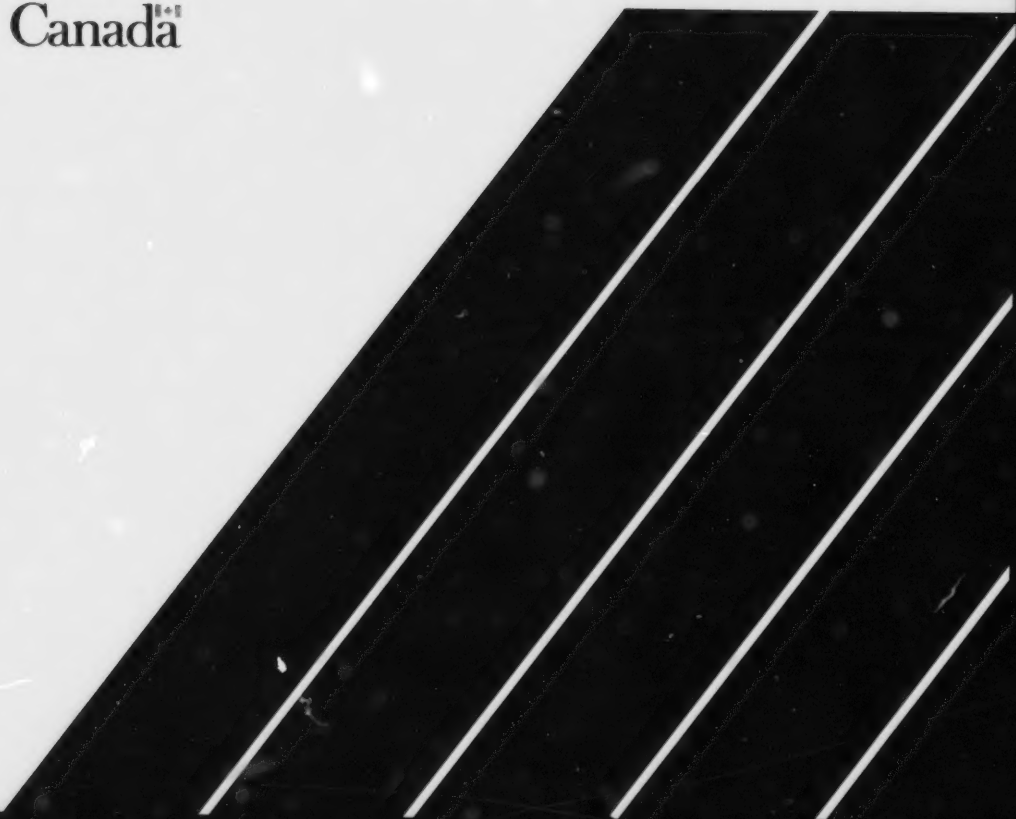
Centre canadien de la
technologie des
minéraux et de l'énergie

**Mineral
Sciences
Laboratories**

**Laboratoires
des sciences
minérales**



Canada



NABST
COMMITTEE ON FEDERAL EXPENDITURES
IN SCIENCE AND TECHNOLOGY
(THE LORTIE COMMITTEE)

BOOK III
CURRICULA VITAE

October 1989

The document is a revised
version of the report prepared by the
National Science and Technology
Advisory Board. It does
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the opinion of the Lortie Committee
on Mineral and Energy Technology
(CANMET).

Le document est une version
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Conseil national de la science et de la technologie
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Comité Lortie sur la technologie des minéraux et de
l'énergie (CANMET).

173 pp

MINERAL SCIENCES LABORATORIES
DIVISION REPORT MSL 89-118 (IR)

MICROMEDIA

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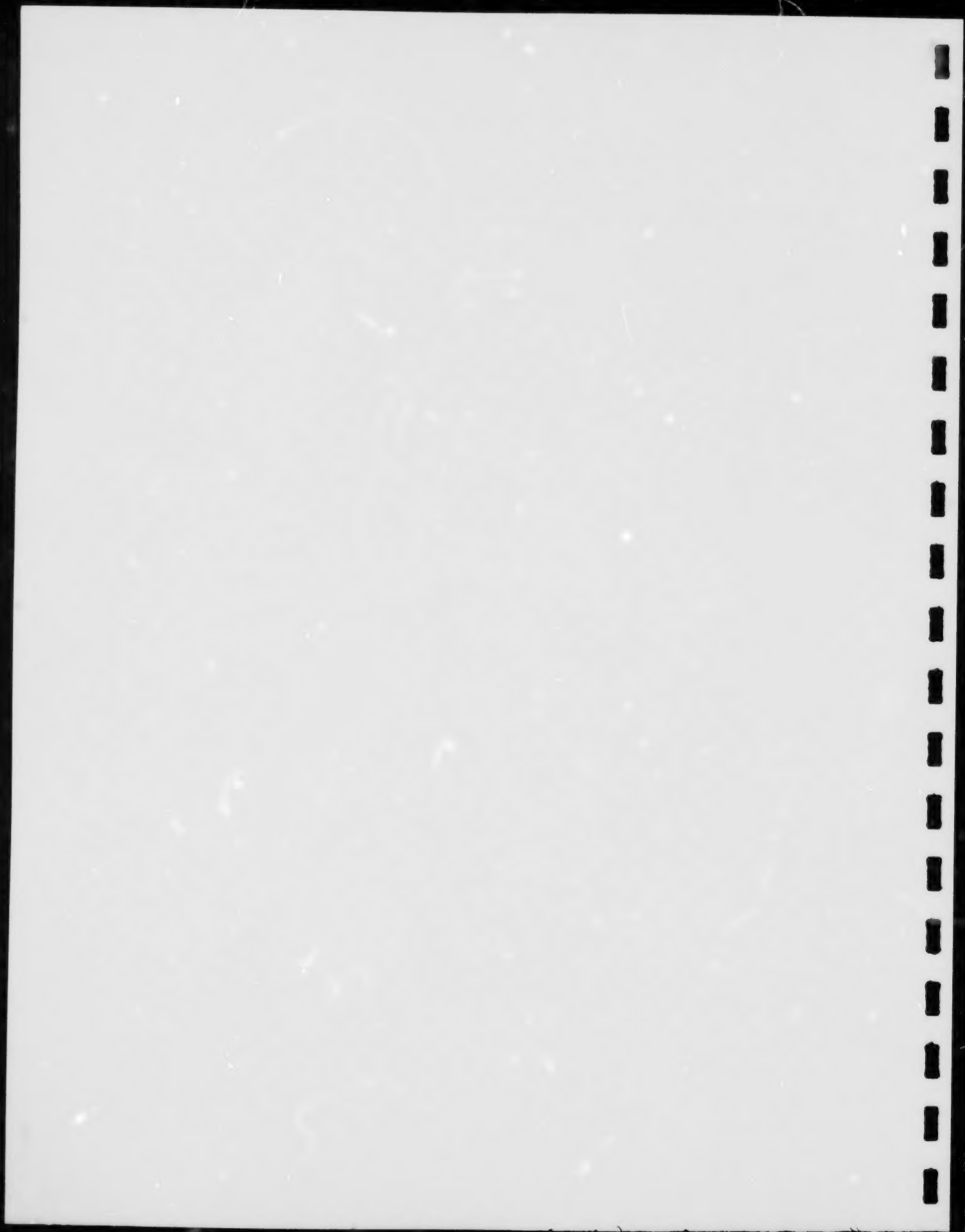
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PROCESS MINERALOGY



CURRICULUM VITAE

NAME: Louis J. Cabri

DEGREES: Ph.D. 1965, McGill University
 M.Sc.(Appld.) 1961, McGill University
 B.Sc.(Hons.) 1955, University of the Witwatersrand
 B.Sc. 1954, University of the Witwatersrand

EXPERTISE:

Research ore mineralogist from the point of beneficiation and recovery aspects, physical and optical properties of minerals, stabilities and phase equilibria of specific mineral systems. Expertise in precious metal minerals (Au, Ag and Platinum-group Elements) with international recognition especially for platinum group minerals. Also expert in development and application of new methods of in-situ trace element analyses of minerals including the proton microprobe, ion microprobe and laser microprobe.

CAREER:

1976 - present	Research Scientist 4, CANMET
1985 - present	Adjunct Professor, University of Ottawa
1974 - 1976	Research Scientist 3, CANMET
1967 - 1974	Research Scientist 2, CANMET
1964 - 1967	Scientific Officer 2, Mines Branch
1959	Field Geologist, New Amianthus Mines, South Africa and Rhodesia (Zimbabwe).
1957 - 1958	Field geologist, Sierra Leone Mineral Syndicate Ltd.
1956	Field geologist, Josan S.A., Gold Coast (Ghana).

PROFESSIONAL AFFILIATIONS:

Honorary Member	Mineralogical Association of Canada.
Fellow	Mineralogical Society of America
Member	Society of Economic Geologists
Editor	Special Issue on Platinum Deposits, Journal of Economic Geologists.
Member	Short Course Committee, Society of Economic Geologists.
Canadian Representative	Commission of Ore Mineralogy, International Mineralogical Association.

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Canadian
Representative

Commission on Ore Deposits in Mafic
& Ultramafic Rocks, International
Association on the Genesis of Ore
Deposits.

Member

Past-Presidents', Medal Committee,
Mineralogical Association of Canada.

AWARDS:

L.J. Cabri (group award) Merit award, presented by Public Service of Canada to the Mineralogy Section.

CURRENT RESEARCH & OTHER ACTIVITIES:

- (a) Zinc recovery: A joint CANMET/Noranda cost recovery project to investigate the possible relationships between the trace element content of sphalerite and sphalerite floatability is in its second year. (15%)
- (b) Refractory gold ores: (i) A joint CANMET/Noranda cost recovery project, consisting largely of consultation time, is concerned with a mineralogical/analytical investigation of the occurrence of gold in refractory gold ores. This project is also in its second year. (5%)
(ii) An analytical investigation of gold in sulphide minerals using both SIMS and macro-PIXE is underway together with Surface Science Western and University of Guelph. (5%)
(iii) Two manuscripts are being prepared (with S.L. Chrissoulis) on the methodology developed for determination of mineralogical balances in refractory gold ores. One of these papers will be presented at the CMP meeting in Jan. 1990. (5%)
- (c) Platinum-group mineralogy: (i) A joint project with Galactic Resources is complete except for the writing up of a comprehensive final report. (10%)
(ii) Two papers for publication (with Dr. G.T. Nixon) are being planned for a just-completed joint project with the B.C. Geological Survey. (10%)
(iii) A paper is being prepared (together with GSC personnel) on the unusual mineralogy of the Fish Hook Bay deposits, Saskatchewan. (5%)
- (d) Cost recovery: Awaiting response to a proposal (\$14,600.00) and preparing another proposal (~\$20,000.00). Two on-going projects (\$20,000.00 for 1989), one nearly completed (\$31,900.00) and one complete in 1989 (\$3,500.00). (15%)

- (e) Administrative, including contracts, technology transfer and preparation time (20%)
- (f) Continuing education: (5%)
- (g) Committee duties, including refereeing & reviewing manuscripts and grant proposals. (5%)

SIGNIFICANT CONTRIBUTIONS:

1. First Canadian Mineralogical Proton Microprobe

The development and application of the proton microprobe (macro -PIXE technique) to trace element problems in ore mineralogy as guest investigator at Heidelberg's Max Planck Institut für Kernphysik (1982-87) and at the Los Alamos National Laboratory (1985) as well as collaborative research with the Bureau de Recherches Géologiques et Minières (Orléans) has led to close work relationship with a Canadian PIXE expert who is internationally recognized, Professor J.L. Campbell, currently Dean of Science, University of Guelph. Modest funding support in the form of CANMET contracts and a joint Campbell-Cabri NSERC grant have led to the successful opening of Canada's first mineralogical Proton Microprobe in late 1987. This facility, located at the University of Guelph has already carried out numerous studies for Canadian industry as well as other government and university researchers.

2. Precious metal distribution in ores

Experiments with the ion microprobe (Secondary Ion Mass Spectrometry) were done at Surface Science Western, University of Western Ontario. After early quantitative work, using synthetic silver-bearing standards, true quantification for trace silver in base metal ores was accomplished. The success with silver, which permitted an accurate silver mineralogical balance in ores such as that of Brunswick Mining & Smelting, led to a CANMET/GSC/DSS supported unsolicited proposal to develop ion probe microanalysis of gold in common sulphide minerals in order to assess the metallurgical implications for enhanced gold recovery from refractory ores. The success of this project, involving participation of nine Canadian mining companies, has led to world-wide interest as it is now possible to determine (within 10%) the mineralogical distribution of gold in refractory gold ores. This provides metallurgical and processing engineers, for the first time, realistic processing options.

3. Surface chemistry of sulphide particles by laser microprobe

A novel approach to study the surface chemistry of sulphide particles from flotation products was initiated with significant qualitative results. This involves use of a Laser Ionization Mass Spectrometer (LIMS) whereby the surface of sulphide particles is analyzed and compared to the subsurface chemistry. The method has great potential and is being developed together with the active participation of Canadian mining companies.

4. Source area for platinum

Careful mineralogical study of platinum nuggets from Tulameen area placer deposits, together with a petrological study of the Tulameen ultramafic complex by the B.C. Geological Survey has resulted in a new approach to determination of the provenance of the nuggets. The latter has been the subject of controversy and these new findings are of great interest to exploration geologists as well as for academic studies on the genesis of platinum deposits.

5. Reference text on platinum

Industry demand for the CIM Special volume "Platinum-Group Elements: Mineralogy, Geology, Recovery", published in 1981, has resulted in a second printing in 1989. This highly regarded text is used widely as a reference, especially by industry.

REFEREED JOURNAL ARTICLES:

Cabri, L.J., Campbell, J.L., Laflamme, J.H.G., Leigh, R.G., Maxwell, J.A. and Scott, S.D. (1985): Proton-microprobe analysis of trace elements in sulfides from some massive sulfide deposits. Can. Mineral., 23, 133-148.

Cabri, L.J. (1986): A third issue devoted to platinum deposits, Preface. Econ. Geol., 81, 1045-1048.

Cabri, L.J. (1987): The mineralogy of precious metals: new developments and metallurgical implications - Presidential address. Can. Mineral, 25, 1-7.

Campbell, J.L., Cabri, L.J., Rogers, P.S.Z., Traxel, K. and Benjamin, T.M. (1987): Calibration of micro-PIXE analysis of sulfide minerals. Nucl. Instr. & Methods in Physics Research, B22, 437-441.

- Remond, G., Cesbron, F., Traxel, K., Campbell, J.L. and Cabri, L.J. (1987): Electron microprobe analysis and proton induced X-ray spectrometry applied to trace elements in sulfides: problems and prospects. *Scanning Microsc.*, 1, No. 3, 1017-1037.
- Cabri, L.J. (1988): Applications of proton and nuclear microprobes in ore deposit mineralogy and metallurgy. *Nucl. Instr. & Methods in Physics Research*, B30, 459-465.
- Mitchell, R.H., Laflamme, J.H.G. & Cabri, L.J. (1989): Rhenium sulphide from the Coldwell Complex, Northwestern Ontario, Canada. *Mineral. Mag.* (in press).
- Cabri, L.J., Chryssoulis, S.L., De Villiers, J.P.R., Laflamme, J.H.G. & Buseck, J.R. (1989): The nature of "invisible" gold in arsenopyrite. *Can. Mineral.* 27, 353-362.
- Chryssoulis, S.L., Cabri, L.J. & Lennard, W. (1989): Calibration of the ion microprobe for quantitative trace precious metal analyses of ore minerals. *Econ. Geol.* 84, (in press).
- Campbell, J.L., Maxwell, J.A., Teesdale, W.J., Wang, J.-X., & Cabri, L.J. (1989): Micro-PIXE as a complement to electron probe microanalysis in mineralogy. *Nucl. Instr. & Methods in Physics Research*, (in press).

REFEREED CONFERENCE PROCEEDINGS:

- Chen, T.T. & Cabri, L.J. (1986): Mineralogical overview of iron control in hydrometallurgical processing. In *Iron Control in Hydrometallurgy*. (Dutrizac, J.E. & Monhemius, A.J. eds.), John Wiley & Sons, 19-55.
- Chryssoulis, S.L., Cabri, L.J. and Salter, R.S. (1987): Direct determination of invisible gold in refractory sulphide ores. *Proceed. Internat. Symp. on Gold Metallurgy-Refractory Gold*, (Salter, R.S., Wyslouzil, D.M. & McDonald, G.W. eds.), Pergamon Press, 235-244.
- Cabri, L.J. (1988): Overview on application of platinum mineralogy to mineral exploration and processing. In *Process Mineralogy VIII*, (Carson, D.J.T. & Vassiliou, A.H. Eds.), TMS-AIME, 23-31, (in press).
- Scoates, R.F.J., Eckstrand, O.R. & Cabri, L.J. (1988): Inter-element correlation, stratigraphic variation and distribution of PGE in the Ultramafic Series of the Bird River Sill, Canada. In *Geoplatinum 87* (Prichard, H.M., Potts, P.J., Bowles, J.F.W. & Cribb, S.J. Eds.), Elsevier, 239-249.

Cabri, L.J. (1988): New developments in determination of the distribution of precious metals in ore deposits. In Proceed. 7th Quadrennial IAGOD Symposium, 149-154.

OTHER CONFERENCE PROCEEDINGS:

Cabri, L.J. (1988): La minéralogie de l'or. Proc. CANMET, Partenaire de l'Industrie Minière Québécoise. (Gaétan, R. ed.), 257-269.

Cabri, L.J. (1988): The role of mineralogy in gold metallurgy. Proc. Symposium on Heap Leaching of Gold in a Canadian Environment. Can. Mineral. Proc., CIM, Paper 2.

BOOKS:

Cabri, L.J. (1989): Platinum-Group Elements: Mineralogy, Geology, Recovery. CIM Special Publication 23, 2nd Printing, 269 p.

AUTHOR IN OTHER BOOKS:

Cabri, L.J. (1986): Platinum Group Metals Resources. Encyclopedia of Materials Science and Engineering (Ed. Beaver, M.B.), Pergamon Press, 3579-3582.

Cabri, L.J. (1989): Platinum Group Metals Resources. Concise Encyclopedia of Mineral Resources (Eds. D. Carr & N. Herz), Pergamon Press, 270-273.

PUBLISHED ABSTRACTS:

Cabri, L.J., Rivers, M.L., Smith, J.V. & Jones, K.W. (1985): Trace elements in sulfide minerals by milliprobe X-ray fluorescence using white synchrotron radiation. EOS, Trans. Amer. Geophys. Union, Abstr., 66, No. 46, 1150.

Campbell, J.L., Teesdale, W.J., Maxwell, J.A. and Cabri, L.J. (1985): PIXE analysis of mineralogical specimens. 32nd Can. Spectroscopy Ann. Conf., Abstr. p. 18.

Cabri, L.J. and Campbell, J.L. (1986). The Micro-PIXE analytical technique in mineralogy. GAC-MAC Ann. Meeting, Prog. with Abstr. 11, 51.

- Cabri, L.J. (1986): The Micro-PIXE technique in studies of some Canadian base metal ores. 14th General Meeting International Mineralogical Association, Abstr., 67.
- Cabri, L.J. (1986): New developments in determination of the distribution of precious metals in ore deposits. Terra Cognita, Abstr., 6, 502.
- Remond, G., Cesbron, F., Campbell, J.L., Traxel, K. and Cabri, L.J. (1986): X-ray spectrometry induced by electron (EPMA) and proton bombardment (Micro-PIXE) applied to trace element analysis in sulfides: problems and prospects. 14th General Meeting International Mineralogical Association, Stanford, Abstr., 208.
- Chryssoulis, S.L., Cabri, L.J. and Salter, R.S. (1987): Direct determination of invisible gold in refractory sulfide ores. GAC-MAC Annual Mtg., Prog. with Abstr. 12, 32.
- Scoates, R.F.J., Eckstrand, O.R. and Cabri, L.J. (1987): Inter-element correlation, stratigraphic variation and distribution of PGE in the Ultramafic Series of the Bird River Sill, Canada. Geoplatinum '87 Symposium, Abstr. Milton Keynes, England.
- Chryssoulis, S.L., Cabri, L.J. and Salter, R.S. (1987): Determination of invisible gold in refractory sulphide ores by SIMS. Internal. Symp. on Gold Metallurgy-Refractory Gold, Abstr., CIM Bull., 80, No. 902, 95-96.
- Cabri, L.J. (1988): Overview on applications of platinum mineralogy to mineral exploration and processing. 117th TMS/AIME Annual Mtg., Phoenix, Abstr., 67.
- Chryssoulis, S.L. & Cabri, L.J. (1989): Mineralogical distribution of gold and its effect on choice of a metallurgical flowsheet. Gold 89 in Europe, Toulouse, Prog. with Abstr. 45.
- Cabri, L.J. & Chryssoulis, S.L. (1989): Analytical techniques for determination of "invisible" gold in refractory ores. GAC/MAC meeting, Montreal, Prog. with Abstr. A68.
- Chryssoulis, S.L., Alcock, R.A., Sizogoric, M.B. & Cabri, L.J. (1989): Quantitative trace PGE analyses of pyrrhotite, pentlandite and millerite. 5th Internat. Pt Symposium, Finland, Prog. with Abstr. 56.
- Cabri, L.J. & Laflamme, J.H.G. (1989): Distribution of PGE in some mineralized zones at the Wellgreen deposit, Yukon, Canada. 5th Internat. Pt Symposium, Bull. Geol. Soc., Finland, No. 61, Pt.1, 26.

Nixon, G.T., Cabri, L.J. & Laflamme, J.H.G. (1989): Provenance of platinum nuggets in Tulameen placer deposits. 5th Internat. Pt Symposium, Finland, Prog. with Abstr., 45.

Chryssoulis, S.L., Cabri, L.J. & Jackman, R. (1989): The application of gold mineralogical balances in metallurgical flowsheet development. CIM Bull., 82, No. 923, 94.

Chryssoulis, S.L., Cabri, L.J. & Singh, S. (1989): Applications of LIMS in mineral and metal recovery. 7th Internat. Conf. on Secondary Ion Mass Spectrometry. Monterey, CA, Prog. with Abstr., 75.

ORAL PRESENTATIONS:

Micro-PIXE in ore mineralogy. Invited presentation Los Alamos National Laboratory, Los Alamos, New Mexico, February 25, 1985.

Mineralogical applications in Particle Induced X-ray analysis (PIXE). Invited presentation at Workshop on Trace Element Geochemistry with Particle and Photon Beams, Brookhaven National Laboratory, N.Y., June 24-28, 1985.

The Micro-PIXE technique in mineralogy. GAC-MAC Annual Meeting, Ottawa, May 21, 1986.

The mineralogy of precious metals: new developments and metallurgical implications. Presidential address, GAC-MAC Annual Meeting, Ottawa, May 20, 1986.

The Micro-PIXE technique in studies of some Canadian base metal ores. 14th Gen. Meeting, International Mineralogical Association, Stanford, July 18, 1986.

New developments in determination of the distribution of precious metals in ore deposits. Invited presentation to the 7th IAGOD Symposium, Lulea, Sweden, August 21, 1986.

Mineralogical overview of iron control in hydrometallurgical processing. International Symposium on Iron Control in Hydrometallurgy, Toronto, October 20, 1986.

Factors affecting recovery of platinum-group elements. Invited Seminar, Toronto Geological Discussion group, Toronto, November 13, 1986.

Mineralogy and recovery of platinum-group elements. Invited speaker to Japanese visiting delegation (MITI), Ottawa, November 17, 1986.

Platinum Group Elements in Polymetallic Deposits. Invited presentation, "Platinum '87", University of Western Ontario, London, February 6, 1987.

Direct determination of invisible gold in refractory sulphide ores. GAC-MAC Annual Meeting, Saskatoon, May 27, 1987.

Trace element analyses (Proton microprobe analyses of copper anodes) presentation to a meeting of the industry-university-CANMET working group on Impurities in Copper Refining, Ottawa, October 26, 1987.

Applications of the nuclear microprobe in ore deposit mineralogy and metallurgy. Invited speaker, 1st International Conference on Nuclear Microprobe Technology and Applications, University of Oxford, September 2, 1987.

Mineralogy of platinum deposits. Invited seminar, University of Aston in Birmingham, England, September 8, 1987.

Recent advances in trace-element microanalysis applications to mineralogy and petrology. Invited seminar, Ottawa-Carleton Centre for Geoscience Studies, Ottawa, October 15, 1987.

Application of the proton microprobe to mineral exploration and mineral processing. Invited presentation, 24th Western Inter-University Geological Conference, Winnipeg, January 23, 1988.

Overview on application of platinum mineralogy to mineral exploration and processing. TMS/AIME Annual Meeting, Phoenix, January 27, 1988.

La minéralogie de l'or. CANMET Seminar, Val-d'Or, Québec, February 25, 1988.

The role of mineralogy in gold metallurgy. Symposium on heap leaching of gold in a Canadian environment, Timmins, May 25, 1988.

Analytical techniques for determination of "invisible" gold in refractory ores. GAC/MAC meeting, Montreal, May 16, 1989.

Mineralogical distribution of gold and its effect on choice of a metallurgical flowsheet. Gold 89 in Europe, Toulouse, May 25, 1989.

Mineralogical forms of gold and the use of sensitive microbeam techniques to quantify "invisible" gold in pyrite and arsenopyrite. Invited talk to Joint CANMET/EEC Seminar on complex sulphide ores, Ottawa, June 27, 1989.

The process mineralogy of the Wellgreen Cu-Ni-Pt-Pd deposit. Invited talk to Outokumpu Oy, Outokumpu, Finland, July 31, 1989.

Distribution of PGE in some mineralized zones at the Wellgreen deposit, Yukon, Canada. 5th Internat. Pt Symposium, Finland, August 2, 1989.

Provenance of platinum nuggets in Tulameen placer deposits. 5th Internat. Pt Symposium, Finland, August 3, 1989.

The proton microprobe analytical technique in the study of trace elements in minerals. Invited lecture to the IGM Institute, USSR Academy of Sciences, Moscow, August 7, 1989.

Implications of mineral surface characterization by laser ionization mass spectrometry to mineral processing. Invited lecture to the IGM Institute, USSR Academy of Sciences, Moscow, August 7, 1989.

Applications of the proton microprobe in mineralogy, geology and metallurgy. Invited lecture to the IGM Institute, USSR Academy of Sciences, Moscow, August 8, 1989.

Invited overseas speaker to the 2nd International Conference on Nuclear Microprobe Technology and Applications, Melbourne, Australia, 5-9 February, 1990 (awaiting permission to go).

CANMET/GSC PUBLICATIONS:

Cabri, L.J. & Laflamme, J.H.G. (1988): Mineralogical study of the platinum-group element distribution from three stratigraphic layers, Bird River Sill, Manitoba. CANMET Rept. CM-IE.

Hulbert, L.J., Duke, J.M., Eckstrand, O.R., Lydon, J.W., Scoates, R.F.J., Cabri, L.J. and Irvine, T.N. (1988): Geological environment of the platinum group elements. GSC Open File 1440.

DIVISIONAL REPORTS:

5 confidential reports for cost-recovery projects.

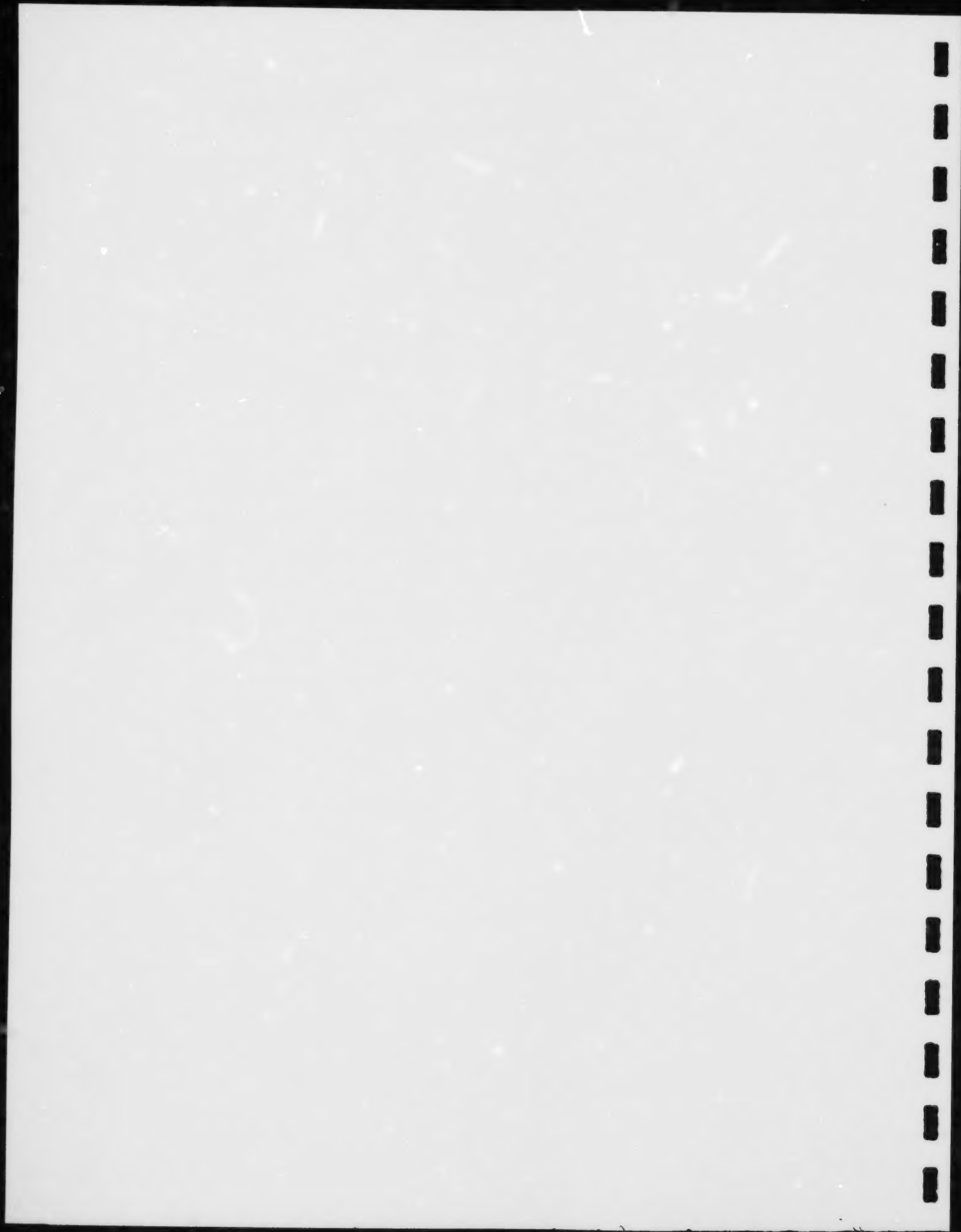
Laflamme, J.H.G. & Cabri, L.J. (1986): Silver and bismuth contents of galena from the Brunswick No. 12 mine. Division report MSL 86-91 (IR).

Laflamme, J.H.G. & Cabri, L.J. (1986): Silver and antimony contents of galena from the Brunswick No. 12 mine. Division Report MSL 86-138 (IR).

Cabri, L.J., Craigen, W.J.S., Pouskoupleli, G. and Stemerowicz, A.E.
(1988): Platinum Metals Recovery. MSL Rept. 88-148 (IR).

PARTICIPATION IN NATIONAL/INTERNATIONAL MEETINGS (OTHER THAN ORAL PRESENTATIONS):

- 1985: President, Mineralogical Association of Canada.
Vice-Chairman, 4th International Platinum Symposium, Toronto
and Chairman for a technical session.
- 1986: Chairman, technical session, International Mineralogical
Association Meeting, Stanford.
Co-Chairman, technical session, & Convener, Special Session
on Current Developments in Microanalysis Applied to
Mineralogy and Geochemistry, Geol. Assoc. Can./Mineral.
Assoc. Can. Annual Mtg., Ottawa.
Canadian Representative; International Mineralogical
Association Annual Meeting, Stanford.
Canadian Representative; Commission of Ore Mineralogy,
International Mineralogical Association, Stanford.
- 1987: Co-Chairman of technical session, Geol. Assoc. Can./Mineral.
Assoc. Can. Annual Mtg., Saskatoon.
Chairman, Technical Session, Geoplatinum '87 Symposium,
Milton Keynes, England.
- 1988: Co-Chairman, Technical session, AIME/TMS Annual Meeting,
Phoenix, Arizona.
- 1989: Convener and Co-Chairman, Technical Session on Analytical
Techniques, International Council on Applied Mineralogy
Symposium, Geol. Assoc. Can./Mineral. Assoc. Can. Annual
Mtg., Montreal.
Chairman, Technical Session, 5th International Platinum
Symposium, Helsinki, Finland.



CURRICULUM VITAE

NAME: John L. Jambor

DEGREES: Ph.D. 1966, Mineralogy and Crystallography, Carleton University
M.Sc. 1960, Geology, University of British Columbia
B.A. (Hon.) 1957, Geology, University of British Columbia

EXPERTISE:

Mineralogy and economic geology of ore deposits, petrography and ore microscopy, and X-ray diffraction studies. Specialization in hydrothermal alteration, especially of porphyry copper-molybdenum deposits, and applications to exploration; expertise in the mineralogical characterization of massive sulphide mineral deposits and applications to predictive metallurgy; experienced in diverse studies of Ag-Ni-Co-As-type deposits, and in rare-earth mineralogy and its significance to processing problems; expertise in oxidation- and gossan-type mineralogy, including mine solid wastes and sulphide-bearing tailings. Internationally recognized authority on determinative mineralogy and mineral nomenclature. Extensive experience in editorial work for scientific journals.

CAREER:

1989 - 1976	Research Scientist 3, CANMET
1984 - 1982	Two-year secondment by Geological Survey of Canada to study massive sulphide deposits in Newfoundland, as part of the Canada-Newfoundland Mineral Development Agreement.
1975 - 1972	Research Scientist 2, Economic Geology Division, Geological Survey of Canada
1972 - 1965	Research Scientist 1-2, Mineralogy Section, Geological Survey of Canada (GSC)
1965 - 1960	Scientific Officer 2-3, Mineralogy Section, GSC

PROFESSIONAL AFFILIATIONS:

Honorary Life Member	Mineralogical Association of Canada
Fellow	Mineralogical Society of America
Fellow	Geological Association of Canada
Fellow	Society of Economic Geologists
Member	Canadian Institute of Mining, Metallurgy, and Petroleum (CIM)
Member	Association of Professional Engineers of Ontario
Vice-Chairman (Chairman-Elect)	CIM Geology Division
Chairman (1989)	CIM Barlow Memorial Medal Committee
Acting Editor-in-Chief (1988-1989)	The Canadian Mineralogist
Member	Finance Committee, Mineralogical Association of Canada (1988-1989)
	CIM Geology Division Technical Program Organizer, 1990 Annual General Meeting
Co-Editor	Special Issue on Seafloor Hydrothermal Mineralization, The Canadian Mineralogist (1989)
Co-Editor	Short Course Handbook on Ore Microscopy, Mineralogical Association of Canada (1990)
Member	Sulphosalt Sub-Committee, International Mineralogical Association
New Minerals Editor	The American Mineralogist (1987-).
Member	Thayer Lindsey Visiting Lecture Committee, Society of Economic Geologists (1988-1991)

AWARDS:

Best technical paper in Transactions of the Institute of Mining and Metallurgy - awarded the Consolidated Gold Fields Silver Medal and Premium for paper with J.E. Dutrizac "The behaviour of silver during jarosite precipitation". (1987)

Member (Head 1987-1988) of the Process Mineralogy Section, to which a Public Service Merit Award (\$5K) was presented for work performance at an unusually high level for an extended period of time. (1988)

CURRENT RESEARCH & OTHER ACTIVITIES:

- (a) **Tailings characterization:** principally a collaborative effort with the Water Research Centre, University of Waterloo. Mineralogy and geochemistry of reactive sulphide-rich tailings at Waite Amulet, Quebec, and Heath Steele, New Brunswick (15%).
- (b) **Water-pollution control:** mainly the characterization of arsenate-bearing compounds, their stability relations, and their possible importance in controlling or stabilizing arsenic in hydrometallurgical products (5%).
- (c) **Impurities in copper refining:** chiefly the determination of the nature of Cu-Zn hydroxychloride compounds and the extent of Cu-Zn solid solution in them (5%).
- (d) **Mineralogy of jarosite-type compounds:** linked to a major project on iron control in hydrometallurgical processing (10%).
- (e) **Mineral nomenclature:** provides authoritative decisions on mineral nomenclature for world-wide dissemination. Other than the use of library facilities, the work is done outside office hours (5%).
- (f) **Rare-earth deposits:** a cost-shared program with Hecla Mining Company to study rare-earth minerals and their deposits. Three-year project with financial support provided annually (10%).
- (g) **Cost-recovery:** current job consists of determinative mineralogy, metal distributions, and potential processing problems for a specific deposit. \$20,000. (15%).
- (h) **Committee duties:** support for scientific and technical organizations (5%).
- (i) **Administrative duties:** attending in-house meetings, preparing memos and fulfilling the needs of the bureaucracy, contract proposals, visitors (25%).

SIGNIFICANT CONTRIBUTIONS:

1. Tailings characterization

Sulphide-rich mine wastes and tailings are highly susceptible to oxidation, thereby leading to the generation of acidic waters and the release of deleterious heavy metals into groundwater systems. Control of acid generation therefore

is not only environmentally desirable, but has become mandatory in recent times despite the high costs involved in acid neutralization and metals control. The world literature is full of reports that deal with the problem, but few of them contain quantitative data and not one contains quantitative mineralogical data integrated with tailings gas and pore-water geochemistry. The methodology of determinative mineralogy and quantitative mineralogy was developed during study of the Waite Amulet tailings, and currently is being extended to tailings impoundments at other sites. A high degree of correlation has been established between observed mineralogy and geochemical modeling; with our new understanding it is possible to suggest solutions to the problem of reactive sulphide tailings. Generation of a hardpan layer at a created buffer zone is a solution recommended in a forthcoming paper by Blowes, Cherry, Reardon & Jambor. These works represent a significant contribution in that, aside from the cooperative research, integrated expertise, and innovative methodology, an appreciable impact is expected in terms of aesthetic improvements, environmental safety, and the financial outlays necessary to control acid drainage.

2. Mineralogy of jarosite-type compounds and process products

Our studies of the composition and X-ray-determined structures of jarosite-type minerals have led to fundamental changes in previous concepts of what these minerals are in terms of their chemistry and crystal structures, how these minerals behave in various hydrometallurgical environments, and why the minerals and their synthetic analogues (i.e., the process products) behave as they do. The contribution of the mineralogical and crystallographic studies, although only one part of broader projects on iron control in hydrometallurgy, and on water-pollution control, should not be underestimated in terms of significance: product characterization has been an essential component in guiding the direction of serial-type syntheses, and in defining the chemical results with respect to solid solution versus multiphase sources. Six new minerals in the system $Pb-Ge-Fe-AsO_4-SO_4$ have been discovered and remain to be described. A paper published as part of this collaborative study was judged to be the best scientific paper in the Transactions of the Institute of Mining and Metallurgy (London) in 1987.

3. Mineral nomenclature

Most new minerals and mineral names are submitted, prior to publication, to a regulatory body known as the Commission on New Minerals and Mineral Names, International Mineralogical Association, which has a panel of experts that reviews the

data submitted, and approves or disapproves of the proposed new mineral and mineral name. Submissions to the IMA are not universal, however, and there also are numerous unnamed minerals, proposed discreditations, and new data that continuously appear in the world literature. The world's foremost mineralogical journal, the American Mineralogist, for several decades has published abstracts and discussions or critiques of relevant minerals that appear in the world's literature. Abridged abstracts also appear in Mineralogical Magazine (Britain), Bull. Mineral. franc. Cryst. (France; now the European J. Mineralogy), and Zapiski Vses. Mineral. Obshch. (Russia), but the leadership of the American Mineralogist can be seen from the fact that an inadvertent slip in this journal generally also appears in the others. The New Minerals Editor of the American Mineralogist independently makes the decisions as to which minerals merit abstracts and critiques; although he does most of the papers himself, he assigns others to a panel of mineralogists (two in the U.S.A., one other in Canada, one in Poland and one in the Netherlands) who are offered advice and guidance in completing their reviews. Results are published regularly in the American Mineralogist. CANMET, the home institution of the current New Minerals Editor, thereby is a centre which provides authoritative expertise in the field of mineral nomenclature, and the influence is world-wide.

4. Mineralogy of massive sulphide ore deposits

Massive sulphide ore deposits are distinguished by having a sulphide content exceeding 60% of the rock, and characteristically having a volcanogenic origin. Most of Canada's lead and zinc, much of its copper, and significant amounts of other metals such as silver and gold are won from massive sulphide deposits. The metallurgical processing of such ores commonly is difficult, and in some cases is not yet possible, because the minerals are fine grained, texturally complex, or both. These negative features are conspicuous in the deposits in New Brunswick and Newfoundland, where considerable assistance has been rendered not only in the processing of these ores, but in the mineralogical characterization of undeveloped deposits. Such studies provide basic documentation that bears directly on the viability of exploiting deposits, of categorizing ore versus waste despite equal metal contents, and of selecting specific processing methods. The influence of such studies was evident in decisions concerning renewed mining of the Caribou deposit, New Brunswick. As well, evaluations or recommendations based on detailed mineralogical studies were made for the Tulks and Tally Pond massive sulphide deposits in Newfoundland. The Newfoundland investigations were undertaken as a result of company requests (Abitibi-Price,

Asarco, Noranda, BP-Selco) that such investigations be conducted during secondment under the Canada-Newfoundland Mineral Development Agreement. Also served as Scientific Authority for three MDA contracts (\$250 K) for study of the Newfoundland deposits.

5. Rare-earth mineral deposits

Exploration for rare-earth deposits is on a world-wide upswing, and Canada is no exception. The deposits are the sources of high-technology metals, the uses of which are expanding rapidly. Current markets for the metals are relatively small, but substantial research is in progress and a promising future seems assured if the financial resources being committed by industry is an indication. The mineralogy of rare-earth ores typically is highly complex and requires expertise both in determinative methods and in assessing the processing implications. Several minerals may harbour a desirable metal, but that metal may not be economically extractable from all of them, and in a worst-case scenario the major mineral source might not be amenable to treatment. Unfortunately, the worst-case scenario is not atypical for rare-earth deposits, and thus precision and reliable quantitative mineralogical results are of critical economic importance. As a result of the significant published contributions made by CANMET in this field, the mining companies in the forefront of rare-earths exploration and development in Canada have sought CANMET expertise through cost-recovery work, and the foremost company is supporting CANMET mineralogical research by means of a three-year cost-shared agreement.

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Jambor, J.L. (1987): Geology and origin of the orebodies in the Lucky Strike area, Buchans, Newfoundland. In Buchans Geology Newfoundland; ed. R.V. Kirkham. Geol. Surv. Can. Spec. Pap. 86-24, 75-106.

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DIVISIONAL REPORTS:

Jambor, J.L. (1985): Comparative mineralogy of the Tulks deposit and a massive sulphide erratic from the Lloyd's River Valley, Buchans area, Newfoundland. Division Report MRP/MSL 85-16, 12 pp.

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Jambor, J.L. (1986): Detailed mineralogical examination of alteration products in core WA-20 from Waite Amulet tailings. MRP/MSL 86-137(IR), 18 p.

Jambor, J.L. (1987): Mineralogical and chemical investigation of cores from piezometric sites in Waite Amulet tailings, Noranda, Quebec. MSL 87-32(IR), 28 p.

Jambor, J.L. (1987): Character and depth of oxidation of the reactive acid tailings at the Waite Amulet minesite, Noranda, Quebec. MSL 87-97(IR), 54 p.

Jambor, J.L. & Owens, D.R. (1987): Mineralogical examination of treated zinc oxide fume leach residues. MRP/MSL 87-49(IR), 13 p.

PARTICIPATION IN NATIONAL/INTERNATIONAL MEETINGS (OTHER THAN ORAL PRESENTATIONS):

1986: Chairman, session on Mineralogy II, Geol. Assoc. Can./Mineral. Assoc. Can. Ann. Mtg., Ottawa.

1989: Co-Chairman and Convenor, Technical Session on Environment and Health, International Council on Applied Mineralogy Symposium, Geol. Assoc. Can./Mineral. Assoc. Can. Ann. Mtg., Montreal.

Co-Chairman, Technical Session on Environmental Impact of Mining Activity. International Council on Applied Mineralogy, Geol. Assoc. Can./Mineral. Assoc. Can. Ann. Mtg., Montreal.

Co-Chairman, Technical Session on Mineral Exploration, CIM Ann. Gen. Meeting, Quebec City.

CURRICULUM VITAE**NAME:** William Petruk**DEGREES:** Ph.D. 1959, McGill University
M.Sc. 1955, University of Saskatchewan
B.Eng. (Geology), 1954, University of Saskatchewan**EXPERTISE:**

Process Mineralogist with emphasis on solving problems related to metal recoveries during processing. Expertise in evaluating the behaviour of metalliferous and industrial mineral ores during mineral beneficiation and in determining the maximum recoveries that can be obtained from particular ores. Extensive experience with many ores such as base metals, iron, silver, and Sn-W. Also has expertise in development, applications and use of image analyzers, particularly with a microbeam image analyzer used for automatic identification of minerals and for determining mineral liberations.

<u>CAREER:</u>	1989 - present	Head, Process Mineralogy Section, CANMET
	1984 - 1989	Research Scientist 4, CANMET
	1975 - 1984	Research Scientist 3, CANMET
	1968 - 1975	Research Scientist 2, Mines Branch
	1960 - 1968	Scientific Officer 2,3 Mines Branch
	1959 - 1960	Sr. Geologist, Canadian Johns-Manville

PROFESSIONAL AFFILIATIONS:

Fellow	Mineralogical Society of America
Fellow	Geological Association of Canada
Member	Canadian Institute of Mining and Metallurgy
Member	Mineralogical Association of Canada
Member	Metallurgical Society, American Institute of Mining and Metallurgical Engineers.
Canadian Representative	International Council on Applied Mineralogy
Canadian Representative	Commission on Applied Mineralogy, International Mineralogical Association.
Editor	Process Mineralogy IX, TMS-AIME.
Chairman	Geology Division, The Canadian Institute of Mining and Metallurgy, 1985.

Chairman	Process Mineralogy Committee, American Institute of Mining and Metallurgical Engineers, 1988-89.
Chairman	International Symposium on Applied Mineralogy, 1987-89.
Chairman	Short Course on Applied Mineralogy to mineral and earth sciences, 1987- 89.

AWARDS:

Petruk, W. (1987) Julian Boldy Award, presented by Geology Division of the Canadian Institute of Mining and Metallurgy for outstanding contributions to Geology Division, CIM.

Petruk, W. (1988) (Group award) Merit Award, presented by Public Service of Canada to the Mineralogy Section in recognition of outstanding contributions by group.

Petruk, W. (1988) Distinguished Lecturer Award, presented by Canadian Institute of Mining and Metallurgy to distinguished persons to make presentations at CIM Branch meetings during 1988-89.

Petruk, W. (1989) Dr. Wright Award, presented by New Brunswick Branch, CIM for distinguished service to the mining industry of New Brunswick.

CURRENT RESEARCH & OTHER ACTIVITIES:

- (a) Integrate Image Analysis System with BILMAT: A technique of taking liberation data from the image analyzer, transferring it to a BILMAT program, and calculating recoveries at each point in a flowsheet by BILMAT without manual data manipulation. All to be done automatically by one computer program. (15%)
- (b) Develop mineral liberation models: One mineral liberation model is to be developed from image analysis data for unbroken ores, and one from liberation data from mill products. The model would be used as input for computer simulations of flowsheet design. A bank of liberation data has been accumulated for different types of ores, and will be used to develop the models. (15%)
- (c) Cost recovery: Numerous small cost recovery jobs for mineralogical. (15%)

- (d) Section head administrative duties. (50%)
- (e) Committee duties. (5%)

SIGNIFICANT CONTRIBUTIONS:

1. Development of automatic microbeam image analysis system

An image analysis system was developed to measure ore and mineral characteristics that affect mineral beneficiation. The main requirements were an image analyzer with an ability to measure mineral liberations, and a scanning electron microscope or microprobe to automatically identify each mineral grain in a sample. A Kontron image analyzer was the only instrument that could perform mineral liberations, and the manufacturer interfaced it to a microprobe equipped with an Energy dispersive X-ray analyzer. Programs for automatic mineral identification, texture analysis and mineral liberation analysis were written. The integrated unit has been widely used to define mineral behaviours during processing, and the technology has been transferred to New Brunswick Research and Productivity Council who have purchased a clone of the image analysis system at CANMET.

2. Technique for evaluating mineral behaviours of ores

A procedure was developed to evaluate mineral behaviour during mineral beneficiation, by determining recoveries of liberated and unliberated mineral grains at each point in a flowsheet. The proportions and sizes of liberated and unliberated mineral grains in samples from a flowsheet were measured with the image analysis system, and a MATBAL materials balance program was used to calculate the flow (recovery) of liberated and unliberated minerals. The information tells the ore dressing engineer whether the concentrator is operating properly, whether all the mineral that can be recovered is recovered, and whether regrinding or other flowsheet modifications are needed. The procedure has been applied to evaluating ores from Brunswick Mining and Smelting, Bathurst, N.B., Kidd Creek Mines near Timmins, Ontario, Trout Lake near Flin Flon, Manitoba, iron ores in the Labrador Trough in Quebec and others. In each case, plant modifications which could improve metal recoveries worth several million dollars per year were indicated.

3. Ore characteristics that affect mineral breakage during grinding

A study was conducted to determine factors that influence breakage of base metal ores in order to assess mineral

liberations obtained by grinding. It was found that breakage occurs in the following order, (1) along major zones of weakness, (2) along poorly bonded grain boundaries, and (3) across grain boundaries. Ores tend to grind readily until most of the poorly bonded grains are separated. If minerals occur in interstices between the grains they are released; if the minerals are enclosed within grains of other minerals, intense grinding and regrinding is needed to liberate the minerals. The behaviour can be readily recognized in most grinding circuits.

4. Characterizing particles recovered in concentrates

The sizes and degrees of liberations of particles that tend to be recovered in concentrates have been determined for many ores. The results provide fundamental information for establishing a grind and desired liberation that must be achieved to recover minerals from an ore. Conditions for obtaining optimum recoveries cannot be defined without the above basic information.

5. Characteristics that affect recoveries of cassiterite from base metal ores

Cassiterite is a minor mineral in base metal ores but, if recovered, can be a major source of tin. The cassiterite in the Kidd Creek base metal ore, which contains about 0.1 wt% Sn, was characterized as a type example. Most of the cassiterite is very fine grained with about 75% occurring as inclusions in sphalerite. Sphalerite is a soft mineral that breaks readily during grinding into small particles and releases the cassiterite inclusions. Hence, about 60% of the cassiterite in the ore is liberated. Cassiterite recovery from volcanogenic base metal ores will involve developing a process that recovers very fine grained liberated cassiterite with a high efficiency.

REFEREED JOURNAL ARTICLES:

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Petruk, W. and Sikka, D.B. (1987): The use of Pink Lepidolite and Tourmaline in prospecting for lithium at the Boanerge lithium deposit, Goias, Brazil. Mining Engineering, 39, No. 2, 123-127.

- Petruk, W. (1988): The capabilities of the microprobe Kontron image analysis system: application to mineral beneficiation. Scanning Microscopy, 2, No. 3, 1247-1256.
- Petruk, W. (1988): Automatic image analysis for mineral beneficiation. Journal of Metals, 40, No. 4, 29-31.
- Petruk, W. (1989): Recent progress in mineralogical investigation related to gold recovery. CIM Bull., Nov. 1989 (in press).
- Petruk, W., Wilson, J.M. and Lewezuk, L. (1989): Characteristics that affect recoveries from the iron ores of the Mount Wright - Carol Lake - Wabush Lake deposits. CIM Bull. (in press).

OTHER JOURNAL ARTICLES:

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- Petruk, W. (1988): L'analyse automatique des images identifie le comportement des minéraux pendant leur valorisation. Geos., 17, No. 3, 17-22.

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- Petruk, W. (1985): Image analysis measurements and data presentations for mineral dressing applications. In Applied Mineralogy (Park, W.C., Hausen, D.M. and Hagni, R.D., Eds.) TMS-AIME, 127-145.
- Petruk, W. (1986): Predicting and measuring mineral liberations in ores and mill products and effect of mineral liberations. In Process Mineralogy VI (Hagni, R.D., Ed.) TMS-AIME, 393-403.
- Petruk, W. and Sikka, D.M. (1987): The formation of oxidized copper minerals at the Malankand porphyry copper deposit in India, and implications on metallurgy. In Process Mineralogy VII (Vassiliou, A.H., Hausen, D.M. and Carson, D.J.T., Eds.) TMS-AIME, 403-420.
- Petruk, W. (1988): Ore characteristics that affect mineral liberation during grinding. In Process Mineralogy VIII (Carson, D.J.T. and Vassiliou, A.H., Eds.). TMS-AIME, 181-193: and In Proceedings Canadian Mineral Processors 1988, CIM.

- Petruk, W. (1988): Automatic image analyses to determine mineral behaviour during beneficiation. In Process Mineralogy VIII (Carson, D.J.T. and Vassiliou, A.H., Eds.) TMS-AIME, 347-357.
- Petruk, W. and Pinard, R.G. (1989): Image analysis evaluation of mineral behaviour during beneficiation: Bench test of a base metal ore from the Faro deposit, Yukon. In Process Mineralogy IX (Petruk, W., Ed.) TMS-AIME (in press).
- Petruk, W. (1989): Mineralogical and image analysis of artificially weathered tailings from the Midwest uranium ore in Saskatchewan. In Process Mineralogy IX (Petruk, W., Ed.) TMS-AIME (in press). Also in CANMET report CM 88-6E. 27 p.
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- Coleman, M.M., Gilders, R.D., May, R.A., Petruk, W. and Surges, L.J. (1989): An investigation of the behaviour of free and unliberated mineral particles in the Brunswick Mining and Smelting Corporation Limited concentrator. In Process Mineralogy IX (Petruk, W., Ed.) TMS-AIME (in press).
- Healey, R. and Petruk, W. (1989): Behaviour of metallic minerals in the HBMS concentrator circuit. In Process Mineralogy IX (Petruk, W., Ed.) TMS-AIME (in press).
- Healey, R. and Petruk, W. (1989): Mode of occurrence and recovery of gold in the Trout Lake deposit, Flin Flon, Manitoba. In Process Mineralogy IX (Petruk, W., Ed.) TMS-AIME (in press).
- Petruk, W. and Pinard, R.G. (1989): Evaluation of concentrator of iron ore Co. of Canada by image analysis and materials balance technique. In Process Mineralogy IX (Petruk, W., Ed.) TMS-AIME (in press).

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- Petruk, W. (1985): Image analysis studies to determine liberation of sphalerite, chalcopyrite and galena during grinding of fine-grained pyritic Zn-Pb-Cu-Ag ores. Proceedings XV International Mineral Processing Congress, BRGM, France, 77-87.
- Smith, M.M. and Petruk, W. (1988): Textural classification using an image analyzer. In Production and Processing of fine particles (Plumpton, A.J., Ed.) CIM, Proceedings vol. 7, 3-13.

- Petruk, W., Chen, T.T. and Wilson, J.M. (1990): Mineralogical characteristics that affect recoveries of galena from base metal ores. In Proceedings Pb-Zn-Sn Symposium (Pregaman, R.D., Ed.) TMS-AIME (in press).
- Petruk, W. (1990): Mineralogical characteristics that affect recoveries of sphalerite from volcanogenic base metal ores. In Proceedings Pb-Zn-Sn Symposium (Pregaman, R.D., Ed.) TMS-AIME (in press).
- Petruk, W. (1990): Mineralogical characteristics that affect recoveries of cassiterite from the base metal ore of Kidd Creek Mines in Ontario. In Proceedings Pb-Zn-Sn Symposium (Pregaman, R.D., Ed.) TMS-AIME (in press).
- Petruk, W. (1989): Image analysis of minerals. In short course on Image analysis applied to mineral and earth sciences. (Petruk, W., Ed.), Can. Mineral. 16, 6-18.
- Petruk, W. (1989): Techniques for performing image analysis routines. In short course on Image analysis applied to mineral and earth sciences. (Petruk, W., Ed.), Can. Mineral. 16, 19-34.
- Petruk, W. (1989): The MP-SEM-IPS image analysis system. In short course on image analysis applied to mineral and earth sciences. Can. Mineral. 16, 37-42.
- Petruk, W. (1989): Image analysis for mineral bonification. In short course on image analysis applied to mineral and earth sciences, Can. Mineral. 16, 86-89.
- Mainwaring, P.R. and Petruk, W. (1989): Automated location of minerals of low abundance using an image analyzer. In short course on image analysis applied to mineral and earth sciences. Can. Mineral. 16, 90-93.

BOOKS:

Short course on image analysis applied to mineral and earth sciences. Petruk, W. Editor, Can. Mineral. vol. 16, 156 p.

AUTHOR IN OTHER BOOKS:

Petruk, W. (1987): Applied mineralogy in ore dressing. In Mineral Processing Design (Yarar, B. and Dogan, Z.M., Eds.), Nato ASI Series E, Applied Science, Martinus Nijinhoff Publishers, 2-36.

SHORT COURSES:

Applied Mineralogy, at Khetri India, Invited by Hindustan copper Limited. March 10-27, 1985.

Image analysis for mineral dressing engineers at Ottawa. Jan. 20 and 24, 1986, Jan. 19, 1987, Jan. 18, 1988 and Jan. 16, 1989.

Image analysis applied to minerals and earth sciences at Ottawa, May 18-20, 1989.

SCIENTIFIC AUTHORITY, CONSULTANT AND VIDEO PREPARATION:

Mineralogical characteristics that affect processing of Zn-Cu-Ag-Au base metal ores from Manitoba. Scientific authority, Manitoba - Federal Government Mineral Deposits agreement. 1985-89.

Mineralogical characteristics that affect recoveries of potash from New Brunswick potash deposits. Scientific authority, New Brunswick - Federal Government Mineral deposits agreement.

Evaluation of mineral behaviour during processing of Brunswick No. 12 ore. Consultant to project carried out by New Brunswick Research and Productivity Council.

Image analysis to determine mineral behaviour during mineral beneficiation. Video, prepared Dec. 1987.

ORAL PRESENTATIONS, INVITED LECTURER OR PLENARY SPEAKER:

Applied mineralogy to mineral benification. IX Annual meeting India Institute of Mineral Engineers, Jamespur, India, March 13, 1985.

Scope of applied mineralogy. Applied Mineralogy Section of MAC, Annual meeting, Fredericton, N.B., May 15, 1985.

Image analysis: an overview of developments. Microscopical Society of Canada, Annual meeting, Fredericton, N.B., May 19, 1985.

Recent developments in process mineralogy of complex sulphide ores. Mineralogy Session, International Symposium on complex sulphide ores, sponsored by AIME/TMS. San Diego, Nov. 13, 1985.

The MP-SEM-IPS image analysis system and its application to Mineralogy and Geology. University visiting lecturer to the CIM Central Ontario District, Laurentian, Lakehead and Windsor Universities, Nov. 17, 18, and 19, 1985.

Evaluating processes for optimum recoveries. Distinguished lecture series, Noranda, West Quebec CIM Branch, Nov. 4, 1988: Kingston, Kingston CIM Branch, Nov. 18, 1988: Whitehorse CIM Branch, Jan. 10, 1989: Thompson CIM Branch, Feb. 12, 1989: Snow Lake CIM Branch, Feb. 13, 1989: Flin Flon CIM Branch, Feb. 14, 1989. Behaviour of gold and silver during processing. CIM distinguished lecturer, Saskatoon Geology Section, CIM, Jan. 12, 1989.

Evaluation of behaviour of iron ore minerals in concentrator of Iron ore Company of Canada. Invited speaker to meeting of Montreal Branch of Canadian Mineral Processors, October 26, 1989.

ORAL PRESENTATIONS AT CONFERENCES AND OTHER MEETINGS:

Relationship between observed mineral liberations in screened fractions and in composite samples. Annual meeting A.I.M.E., New York, Feb. 25, 1985.

An SEM-based image analysis system for solving complex mineral dressing problems. Annual meeting, A.I.M.E., New York, Feb. 25, 1985.

Use of pink lepidolite and tourmaline in prospecting for lithium at the Boanerge Lithium deposit, Goias, Brazil, Annual meeting, A.I.M.E., New York, 1985.

Applied mineralogy to mineral dressing. Engineers and Geologists of Malanjkhand Copper Mines Ltd. at Malanjkhand, India, Marc 14, 1985.

Applied mineralogy, exploration and mineral beneficiation. Delhi Chapter of Mining, Geological and Metallurgical Institute of India, March 28, 1985.

Image analysis studies to determine liberation of sphalerite, chalcopryrite and galena during grinding of fine-grained pyritic ore Zn-Pb-Cu-Ag ores. Poster Session XV Intl. Mineral Processing Congress, June 3, 1985.

Removing sulphur from N.S. coal. A.I.M.E. Annual Meeting, New Orleans, Mar. 3, 1986.

Predicting and measuring mineral liberation in ores and mill products and effect of mineral texture and grinding methods on mineral liberations. A.I.M.E. Annual Meeting, New Orleans, Mar. 4, 1986.

Pelletizing iron ore. A.I.M.E. Annual Meeting, New Orleans, Mar. 5, 1986.

The MP-SEM-IPS image analysis system and its application to mineralogy and geochemistry. MAC, Annual Meeting, Ottawa, May 21, 1986, and to Geology class, University of Manitoba, at Winnipeg, Oct. 27, 1986.

Development of an automated SEM-IPS-IA image analysis system, Int. Mineralogical Assoc., 14th General Meeting, Stanford, July 16, 1986.

Predicting and measuring mineral liberations in ores and mill products, and effect of mineral textures and grinding methods on mineral liberations. Metsoc, C.I.M. Annual Meeting, Toronto, Aug. 20, 1986.

The formation of secondary copper minerals at the Malanjkhand copper deposit in India and implications on mineral beneficiation. Denver, CO, AIME, Annual meeting, Denver, CO., Feb. 25, 1987.

Factors that control the breakage of an ore during grinding. AIME, Annual meeting, Denver, CO., Feb. 26, 1987.

Ore characteristics that affect mineral liberation during grinding. Canadian mineral processors, Annual meeting, Ottawa, Jan. 20, 1988.

Method of studying materials by image analysis and applications to Earth Sciences. 24th Western inter-university Geological Conference, Winnipeg, Jan. 21, 1988.

Textural classification using an image analyzer. Annual METSOC CIM, Annual meeting, Montreal, Aug. 29, 1988.

Applied mineralogy to evaluate mineral and metal recoveries from ores of Atlantic Provinces. CIM, District 1, Annual meeting, Fredericton, N.B., Sept. 21, 1988.

Recent progress in mineralogical investigation related to gold recovery. Joint CANMET-Ontario Mining Association meeting, Timmins, Ont., Nov. 24, 1988.

Ore characteristics that affect mineral beneficiation during grinding. Annual meeting of EEC and CANMET, Luxembourg, Nov. 29, 1988.

Image analysis evaluation of mineral behaviour during beneficiation: bench test of a base metal ore from the Faro deposit, Yukon. AIME, Annual meeting, Las Vegas, Feb. 28, 1989.

Mineralogical and image analysis of artificially weathered tailings from the Midwest uranium ore in Saskatchewan. AIME, Annual meeting, Las Vegas, Mar. 1, 1989.

Recent progress in mineralogical investigations related to gold recovery. CIM, annual meeting, Quebec, May 2, 1989.

Characteristics that affect recoveries from the iron ores of the Mount Wright - Carol Lake - Wabush lake deposits. CIM annual meeting, Quebec, May 3, 1989.

Factors that affect recoveries of iron ore by the Mount Wright spiral circuit. International conference on applied mineralogy, Montreal, May 15, 1989.

Measurement of mineral liberation in connection with mineral beneficiation. International conference on applied mineralogy, Montreal, May 15, 1989.

CANMET REPORTS:

Petruk, W. and Mainwaring, P.R. (1985): Recent developments in Process Mineralogy of complex sulphide ores. CM 85-12E and CM 85-12F.

Petruk, W. (1986): Image analysis: an overview of developments. CM 86-4E and 86-4F.

Petruk, W. (1986): The MP-SEM-IPS image analysis system. CM 87-1E.

Petruk, W. and Smith, M.M. (1988): Ore characteristics that affect breakage during grinding. CM 88-5E.

Petruk, W. and Pinard, R.G. (1988): Mineralogical and image analysis study of artificially weathered tailings from the Midwest uranium ore in Saskatchewan. CM 88-6E.

DIVISIONAL REPORTS (Confidential - Cost Recovery):

14 Cost-recovery confidential reports (about 10 pages per report).

SECTION REPORTS (Confidential - Cost - Recovery not processed as Divisional reports to save time for release):

14 Cost-recovery reports 2 to 51 pages, average size about 10 pages.

PARTICIPATION IN NATIONAL/INTERNATIONAL MEETINGS (other than oral presentations):

Chairman, Geology Division meeting, Canadian Institute of Mining and Metallurgy (CIM), Vancouver, April 1985.

Chairman, Technical session, annual meetings of AIME, New York, Feb. 1985, New Orleans Feb. 1986, Denver, Feb. 1987, and Las Vegas, February 1989.

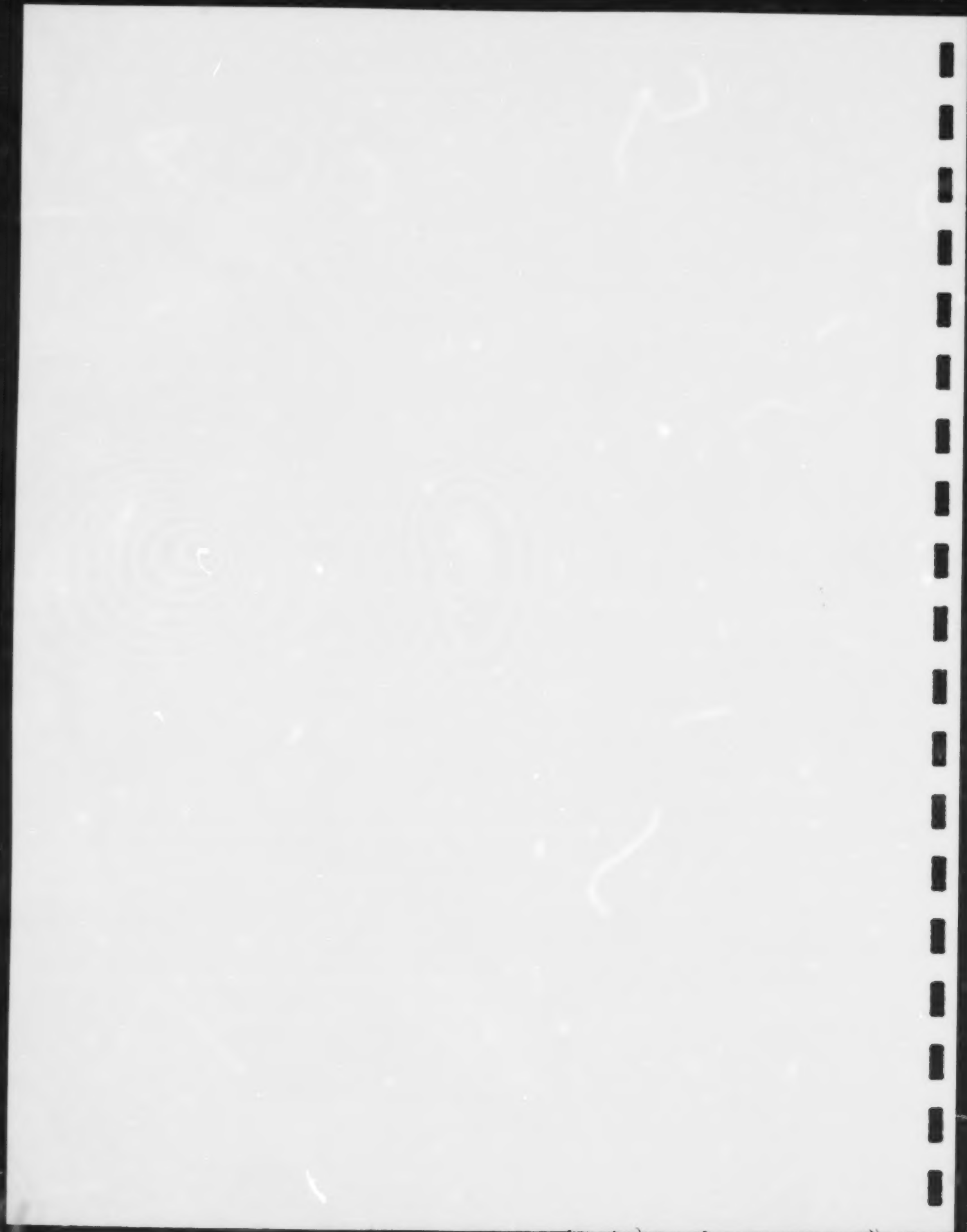
Chairman, Technical Session, International Mineralogical Association meeting, Stanford, July 1986.

Executive member, Process Mineralogy committee, AIME annual meetings, New York 1985, New Orleans 1986, Denver, 1987.

Chairman, Process Mineralogy meeting, AIME, Las Vegas, Feb. 1989.

Chairman, International Symposium on applied mineralogy, Montreal, May 1989.

MINERAL DRESSING



CURRICULUM VITAE

NAME: Wayne H. Cameron

DEGREE: B.Sc. (Honours Geological Sciences) 1973, Queen's University

EXPERTISE:

Physical Scientist. Iron ore processing. Mineral processing basic and applied research in gravity separations, flotation, magnetic separations, electrostatic separations, heavy liquid/media separations, and pelletization of iron ores. In depth knowledge of crushing and grinding, classification systems, slurry pumping and transportation, process control and tailings disposal. Considerable experience in mathematical modelling and simulation and beneficiation of industrial minerals. Expertise in small particle measurements.

CAREER: 1975 - present Physical Scientist 3, CANMET
1973 - 1975 Party Chief, geological, geochemical and geophysical exploration C.F. Gleeson & Associates, Ottawa

PROFESSIONAL AFFILIATIONS:

Member Canadian Institute of Mining and Metallurgy

CURRENT RESEARCH AND OTHER ACTIVITIES

- (a) Iron Ore Producers Real Time Control Investigations: A joint cooperative cost sharing project involving CANMET (MSL), Iron Ore Co. of Canada, Quebec Cartier Mining, Ramsey Ltd. and Corrigan Instrumentation Ltd. A state-of-the-art pilot plant is being established at MSL's Ore Dressing Section. Instrumentation and process controls will be installed in various configurations to simulate problem areas in flowsheets of the two participating mines. Ramsey of Canada and Corrigan Instrumentation Ltd. will supply and install the necessary instrumentation and controls. Other equipment manufacturers/suppliers may be asked to install and supply specific proprietary pieces of equipment.

The total cost of the project is \$1665.0 K over a period of three years. Meetings with the participating mines have taken place, project elements have been prioritized and the project is just getting underway (65%).

- (b) Administrative, including contracts, technology transfer and interim Section Head (20%)
- (c) Continuing education: (5%)
- (d) Committee duties including Task Force and coordinating Iron Ore Symposium for next August's METSOC convention (10%).

SIGNIFICANT CONTRIBUTIONS:

1. Establishment of Iron Ore Technical Task Force Committee

In January 1986, this group held its first meeting in Ottawa. Members are comprised of representatives of all Canadian iron ore producers, various federal and provincial governments, members of other research institutions and universities. I have acted as chairman of the group since its formation.

Since 1986 the Committee has held two meetings per year, one each January in Ottawa and another each September at the site of one of the iron ore producers. The Task Force serves to prioritize industry's research needs, to influence CANMET's research program and to develop funding arrangements for identified priorities.

2. Iron Ore Producers Real Time Control Investigations

This joint cooperative project involves CANMET, the two largest Iron Ore Producers (only four are left) and equipment suppliers/manufacturers. The project is being conducted at CANMET and will develop process control methods at pilot plant scale for subsequent implementation by industry. The project took over one year to package into a final agreement when competing producers were convinced to cooperate in this major joint, cooperative project which is expected to cost over \$1.5M over three years.

3. Geostatistical Grade Control

Geostatistical grade control methods for the mill feed at the QCM concentrator leveled out grade fluctuations to the mill with a resultant reduction in down time.

4. Densimetric Curves

Heavy liquid separations were carried out and the resultant densimetric curves were used by the sponsor with an appreciable increase in grade and recovery. (confidential cost recovery).

CANMET PUBLICATIONS:

Cameron, W.H. & Feader, W.C. (1985): Simulation of a Rotary Vacuum Filter (VACFIL). SPOC Manual, Chapter 5.2, Unit Models (Part C), (pgs. 53-60).

DIVISIONAL REPORTS:

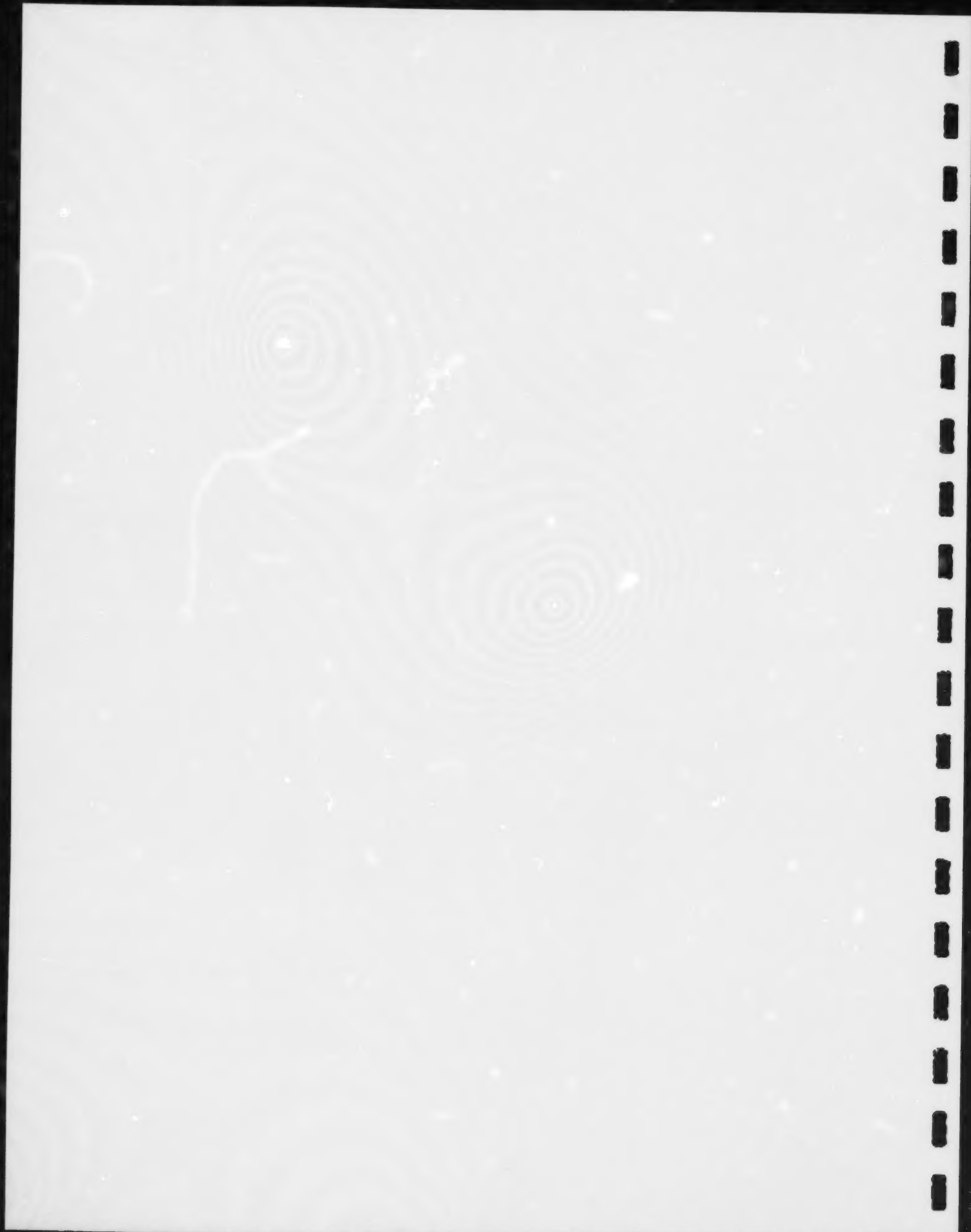
J. Leung and W. Cameron (1987): Investigation to improve the dewatering of the thickeners in QCM iron ore plant. Division report MSL 87-23 (IR).

Cameron, W.H. and Reynolds, V.G. (1988): Investigation to produce an iron concentrate of low manganese content from Wabush rougher spiral tailings. Division report MSL 88-39 (IR).

Cameron, W.H. (1985) & (1986): 2 confidential cost recovery reports.

PARTICIPATION IN NATIONAL/INTERNATIONAL MEETINGS(other than oral presentations):

1986-1989: Chairman and Secretary, Iron Ore Technical Task Force



CURRICULUM VITAE

NAME: D. Grant Feasby

DEGREES: M.Sc., 1965, Metallurgical Engineering, Queen's University
B.Sc., 1964, Metallurgical Engineering, Queen's University

EXPERTISE:

Mineral processing research, extractive metallurgy of uranium, environmental control and waste management, mineral processing plant operation.

CAREER:

1987 - present:	Head, Industrial Minerals Section, CANMET
1983 - 1987:	Project Manager, National Uranium Tailings Program, CANMET
1979 - 1983:	Mill Superintendent, Eldorado Nuclear, Saskatchewan
1975 - 1979	Senior Metallurgist, Eldorado Nuclear, Ottawa
1972 - 1975	Physical Scientist, CANMET
1968 - 1972	Research and Applications Engineer, Eldorado Nuclear, Ottawa
1966 - 1968	Plant Metallurgist, Brunswick Mining and Smelting, New Brunswick
1965 - 1966	Minerals Research Engineer, Minerals Research Laboratory, Asheville, North Carolina, USA
1964	Pilot Plant Engineer, Eldorado Mining and Refining, Ottawa

PROFESSIONAL AFFILIATION:

Member	Canadian Institute of Mining and Metallurgy
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CURRENT RESEARCH AND OTHER ACTIVITIES:

1. Mineral Development Agreements

The current Mineral Development Agreements with Nova Scotia and Saskatchewan are in the "wrap-up year", and 3 contracts started in previous years are being administered. In addition to this contract management, documentation is being prepared for year-end meetings that will detail and account for the expenditure of funds during the agreements. On the expectation that the agreements will be renewed in the fiscal year 1989-90, extensive consultation is being undertaken with provincial governments and the mineral industry in the respective provinces to develop worthwhile projects in which the mineral industry is willing to contribute time and money. A typical project is to develop the technology to recover a mineral that is presently being wasted from a tailings stream. (20% of time)

2. Cost recovery

Cost recovery work is varied, ranging from mineral process investigations to multi-disciplinary studies on material properties. Routine mineral process investigations are referred to commercial laboratories, and work that requires CANMET expertise or specialized equipment is accepted. At any one time there will be 2 or 3 cost recovery projects underway, and proposals will have been prepared for 5 or 6 more. (25% of time)

3. Saskatchewan Potash Producers Association (SPPA)

Liaison with the Research Committee of the SPPA takes the form of attending committee meetings, administration of contracts, and discussion of future research in mineral processing, environment, and product handling. (10% of time)

4. Mineral Processing Investigations

Independently and in cooperation with the mineral processing industry, investigations are done in the laboratory. A shared- cost project on the production of a high quality mineral filler from a Newfoundland calcite deposit is nearing completion. Investigations continue on the beneficiation and preparation of special mineral products, eg., the preparation of a finely ground and delaminated mica that would be suitable in a metal-mineral composite material. (10% of time)

5. Administration

Administration of Industrial Mineral Section, personnel and safety matters, assistance to laboratory management. (25% of time)

6. Technology Transfer

There are frequent inquiries from the mineral industry and from the general public on a wide range of technical subjects related to minerals processing in Canada. (10% of time)

SIGNIFICANT CONTRIBUTIONS:

1. Management of the Technology Component of the National Uranium Tailings program

The National Uranium Tailings Program, 1982 - 1987, was an \$8M multi-disciplinary research program that studied all aspects of the disposal of wastes from the processing of uranium ores. Under the critical review of the uranium industry and provincial and federal regulatory agencies, contracts were placed in the private sector, universities and research institutions to examine all technical aspects of disposal technology. Included in this examination was the incorporation of technical data into a model that would predict future effects of each chosen technology, and give a measure of future risk to the public. A technology manual titled "Uranium Mill Waste Disposal Technology" has been accepted by the Atomic Energy Control Board (AECB) in Canada, and by the International Atomic Energy Agency as the definitive document on the subject.

2. Coordination of Federal-Provincial Mineral Development Agreements, Saskatchewan and Nova Scotia

Under federal-provincial programs to foster the development of mineral resources CANMET has managed a large number of contracted-out R&D projects. Contracts were let to the mineral industry and to universities and the overall program was coordinated with the activities of other sectors of Energy Mines and Resources and with provincial counterparts. In Saskatchewan, the work was exclusively concerned with the potash industry, and the work was contracted mainly to the individual mining companies and costs were shared with CANMET. This cost-shared approach has fostered close cooperation in the industry which has resulted in a proposed 5-year research program costing \$8 million to be shared equally by Saskatchewan, the federal government and the industry. In Nova Scotia, the contract research and

development has centered on the province's industrial mineral potential, and new developments are taking place as a result of the work. An example of this new development is the use of anhydrite as mine support material in Cape Breton coal mines, a test of which has recently been successfully completed.

3. Organization of a Symposium on Column Flotation Technology

The column cell mineral concentrator is a Canadian-developed device that has suddenly gained wide acceptance in the mineral industry. The unusual aspect of this technology is that its refinement has been the result of developments on the plant floor by individual operators, rather than equipment suppliers. In November 1987, Canadian and international operators of column cells were invited to participate in a 3-day seminar to exchange technical information on design and operation of the equipment, and applications in various mineral processing plants. CANMET and Cominco co-hosted the discussions and the recorded proceedings have assisted in further applications and developments. CANMET has subsequently developed with several Canadian companies a multi-year cooperative research program that will further improve the technology.

ORAL PRESENTATIONS:

"Activities in Industrial Minerals in CANMET"; Presentation at the 1988 Federal-Provincial meeting on industrial minerals.

"Industrial Minerals and the Canada-Nova Scotia Mineral Development Agreement"; invited presentation at the Nova Scotia Department of Mines and Energy Open House, November 1988

"Research Opportunities and Needs in the Saskatchewan Potash Industry"; invited presentation to the Saskatchewan Potash Producers Research Committee, September 1989

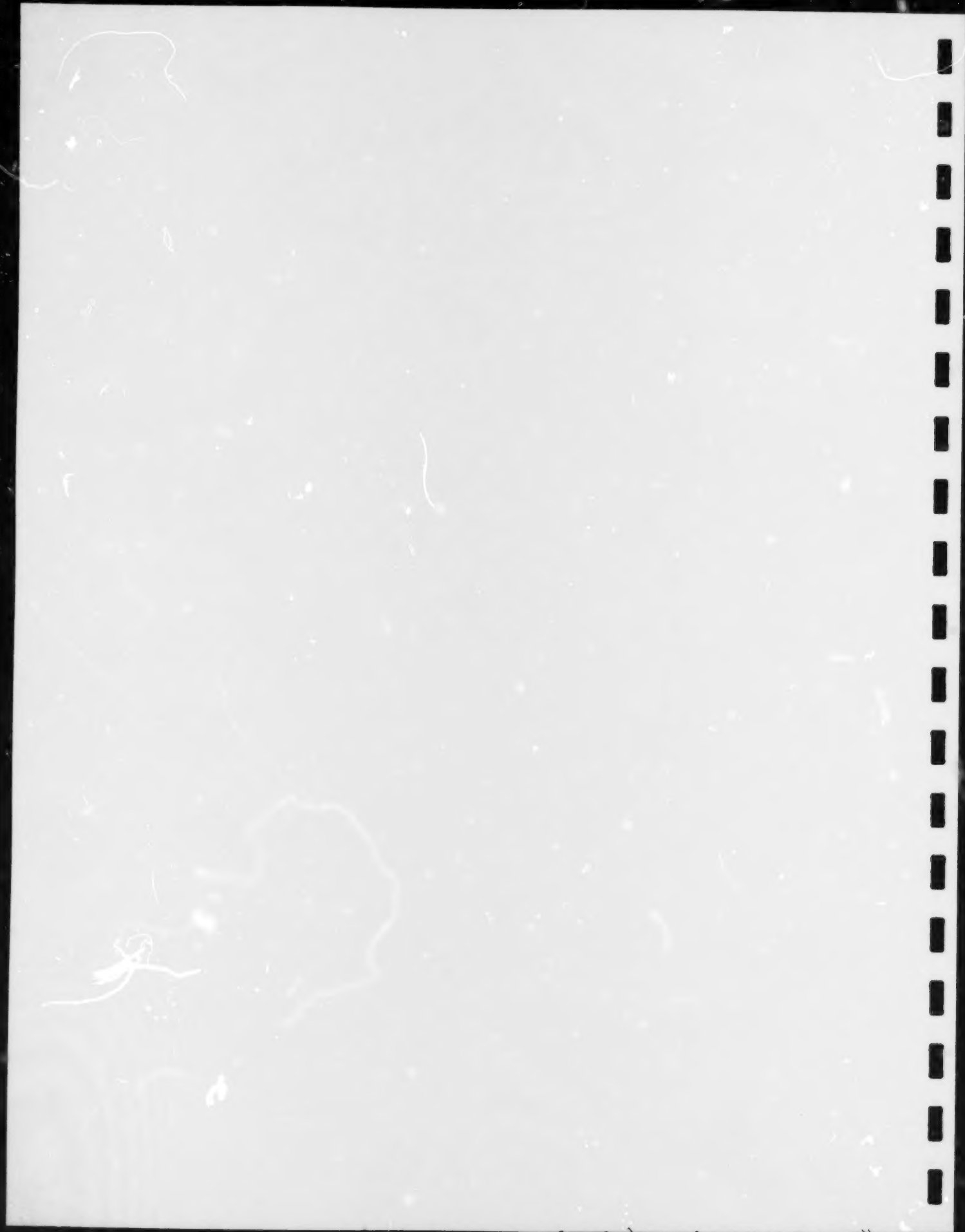
CANMET PUBLICATIONS:

Feasby, D.G. (1982 -1987): The National Uranium Tailings Program, Summary Report, Disposal Technology

Feasby, D.G., Industrial Minerals in Canada: The Federal-Provincial Mineral Development Agreements, CANMET Division Report MSL 89-25.

CONFERENCE PROCEEDINGS:

Feasby, D.G., (November 1988): Symposium Proceedings, Column
Flotation, Trail, British Columbia.



CURRICULUM VITAE

NAME: Gilles I. Mathieu

DEGREES: D.P.A. (Public Administration), 1972, Carleton University
 B.Com. (Commerce), 1969, University of Ottawa
 B.A. Sc. (Metallurgical Engineering), 1960, Laval University
 B.A. (Arts-Philosophy), 1956, Laval University

EXPERTISE:

Research on coal preparation, ore processing and mineral beneficiation, in particular, on de-ashing and desulphurization of eastern Canada coals, on flowsheet development for treating complex tungsten-molybdenite-bismuth, silica-feldspars and antimony ores, as well as upgrading of wolframite, pyrochlore and industrial minerals to market specifications. Also, studies and solution of problems of environmental concern, such as cyanide destruction and removal of noxious and toxic material from waste. Authority in magnetic separation theory and applications; inventor of a non-ferrous metal sorter based on eddy-current induced force. Scientific adviser on several coal processing and pyrochlore beneficiation projects.

<u>CAREER:</u>	1983 - present	Research Scientist 3, CANMET
	1976 - 1983	Research Scientist 2, CANMET
	1975 - 1976	Senior Research Metallurgist, AMAX
	1970 - 1975	Research Scientist 2, CANMET
	1965 - 1970	Research Scientist 1, CANMET
	1960 - 1965	Scientific Officer 1, 2, Mines Branch

SIGNIFICANT CONTRIBUTIONS:

1. Conception, Design and Construction of a Metal Separator

To help the aluminum industry to recycle fragments of Al metal currently lost in waste products, a novel non-ferrous metal sorter was designed and constructed at CANMET. It was tested with success in our laboratories and, currently, is being evaluated on a pilot plant scale by industry. The costs of the development are being paid by industry, but the prototype model will remain the property of CANMET. CANMET is contemplating other applications of the apparatus in the field of scrap sorting, domestic garbage, metal recovery in foundries, etc.

2. Beneficiation of Black Pyrochlore

Significant tonnages of a ferrous type pyrochlore were found in a Canadian operating mine. The beneficiation of this niobium mineral raised serious concern, because of the concomitant concentration of undesirable impurities (pyrite, in particular, since the market requires a product containing less than 0.15% S). A new differential flotation technique was found, tested in our laboratories and is being implemented in plant practice. The selective removal of pyrite by flotation resulted in niobium concentrates with less than 0.1% S with pyrochlore recoveries of 98 to 99%.

3. Treatment of Spent Potlining of Aluminum Producers

Every year, Canadian aluminum producers have to dispose of thousands of tons of waste products. The storage, recycling and conversion of these constitutes a major economic and environmental concern to the aluminum industry. Spent potlining is notable in this respect with values in aluminum, steel, carbon and cryolite, along with barren brick and undesirable soluble ammonia, fluorine and cyanide. The material was characterized and various approaches were investigated to recover the metal and the combustibles. New techniques of sorting were tested and a process to destroy some contaminants while recovering the fluorine in the gases was recommended. The research study was sponsored by industry.

4. Sulphur Removal from Eastern Canada Coals

A novel approach was investigated to reduce sulphur in Eastern Canadian coals to an acceptable level. It consisted of progressive comminution and cleaning, i.e. elimination of sulphides as soon as liberated at minimal grinding costs. The method was applied to three different Canadian coals. The upgrading studies were supported by mineralogical examination of the products. A good correlation was obtained between liberation and elimination of contaminants (sulphur-and ash-bearing minerals). The beneficiation involved both flotation and high-gradient magnetic separation.

5. Dry Coal Preparation using Rare-Earth Magnetic Rolls and HGMS Separators

Pioneer work was conducted in our laboratories and contracted outside for applications of novel types of magnetic separators to dry beneficiation of coals. Rare-earth cobalt-samarium and neodymium-boron-iron units were tested on coarse material, while high-gradient conventional and superconducting magnet systems were tested on fines. The performance of the various

separators was compared on eastern and western Canadian coals at various size ranges. The study indicated new avenues for cleaning coal by processes which do not require a large water supply and subsequent effluent cleaning.

CURRENT RESEARCH AND OTHER ACTIVITIES:

Currently working on testing, evaluating and improving a metal sorter developed at CANMET. Promotion and technology transfer in the sector of aluminum primary and secondary production is underway. Other fields of application are being surveyed for the current design and design improvements will be incorporated for other applications. (30%)

Preparation of contracts, conducting research studies and preparing reports, notably on pyrochlore beneficiation by column flotation and on approaches to problems of environmental concern. These projects are essentially on a cost recovery basis and therefore confidential. (60%)

Other duties (administrative, training, etc.). (10%)

REFEREED CONFERENCE PROCEEDINGS:

Mathieu, G.I. and Sirois, L.L., (1988): "Advances in technology of magnetic separation", in Proceeding of the XVI International Mineral Processing Congress (Forssberg K.S.E. ed.), Elsevier, 937-950.

Mathieu, G.I. and Mainwaring, P.R., (1986): "Mineralogy and Deep Cleaning of Canadian High Sulphur Coals" in Process Mineralogy IV, (Gagni R.D. ed.), AIME Publications, 343-363.

Mathieu, G.I. and Sirois, L.L., (1985): "New processes to float feldspathic and ferrous minerals from quartz" in Reagents in the Mineral Industry, (Jones, M.J. and Oblatt, R. eds), Stephen, Austin/Hertford, 57-67.

OTHER CONFERENCE PROCEEDINGS:

Mathieu, G.I., (1989): "Le rôle de la minéralurgie dans l'exploitation d'un gisement" in Actes du Séminaire CANMET: Partenaire de l'Industrie Minière Québécoise. (Gaétan, R. ed.).

Mathieu, G.I., (1988): "Historical evolution of magnetic separation" in Proceedings - 20th Annual Meeting of the Canadian Mineral Processors. (CANMET - CIM ed.), 339-364.

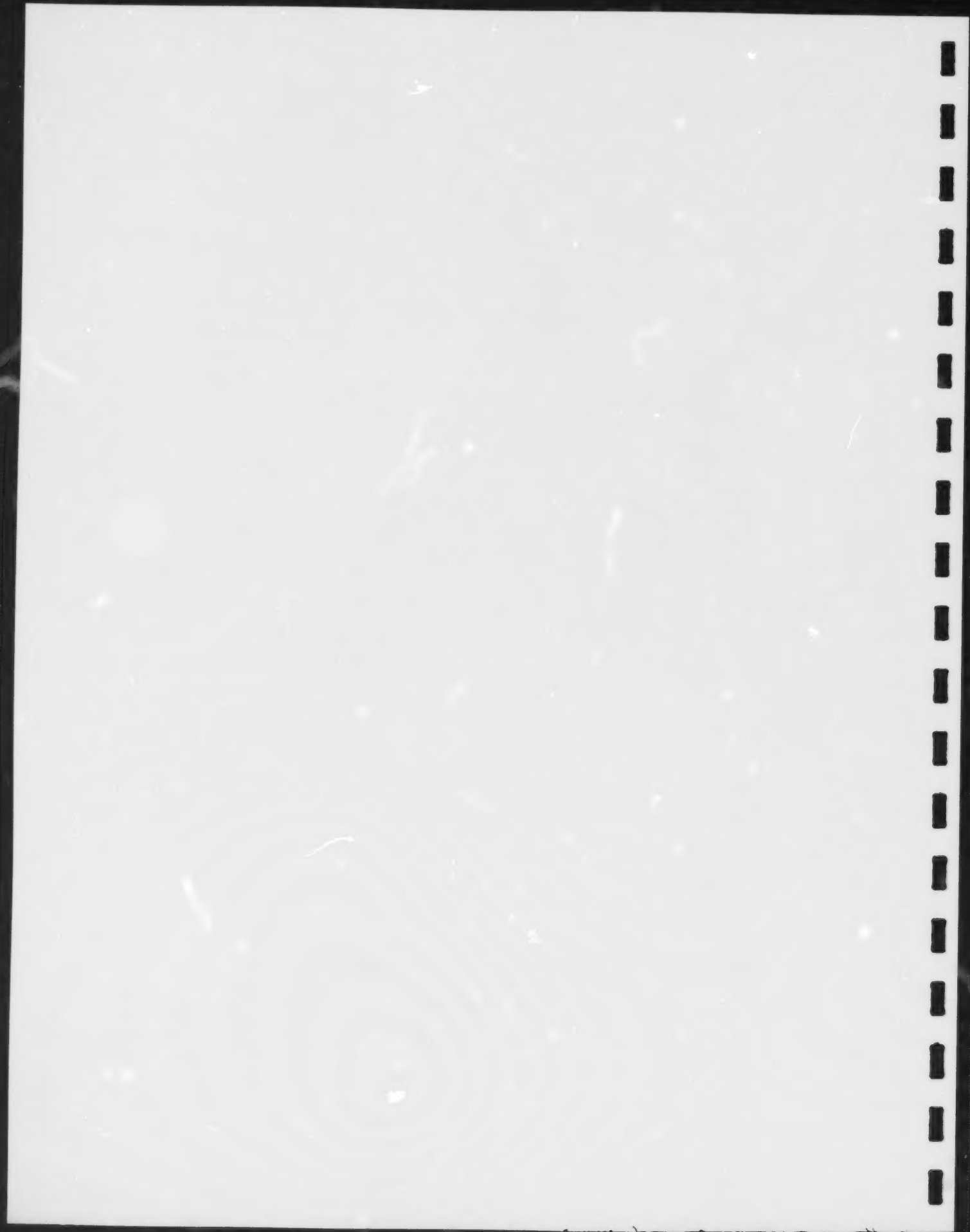
ORAL PRESENTATIONS:

- Mathieu, G.I., (1987): "Mineralogy and intensive cleaning of Donkin- Morien Coal", Coal Prep. 87 Conference, Lexington, KY, April 27-29, 1987.
- Mathieu, G.I., (1985): "Deep cleaning of coal by progressive processing approach". Presentation upon invitation at Engineer Foundation Symposium on Science and Technology of Processing Fine Coal, Henniker, N.H., May 11, 1985.
- Mathieu, G.I., (1986): "Mineralogy and Deep Cleaning of Canadian High-Sulphur Coals". Presented at AIME-TSM Annual Meeting, New Orleans, LA., March 5, 1986.
- Mathieu, G.I., (1985): "Dry cleaning of coal: Existing and new technology", Presented at CIM Annual Meeting, Vancouver, April 1985.

DIVISIONAL REPORTS:

- Mathieu, G.I., Provencher, R. et Tellier, J.G., (1989): "Mechanical sorting of aluminum metal from spent potlining", Division Report MSL 89-103 (OP&J). For presentation at the "Reduction and Environmental Session" of the 119th AIME Annual Meeting at Anaheim on February 21, 1990 and for subsequent publication in Lights Metals 1990.
- Mathieu, G.I., (1987): "Mineralogy and deep cleaning of Canadian high-sulphur coals: Report No. 2," Division Report MSL 87-47 (IR).
- Mathieu, G.I., (1986): "Mineralogy and deep cleaning of Canadian high-sulphur coal: Report No. 1", Division Report MSL 86 (IR).
- Mathieu, G.I., (1985): "Dry cleaning of coal: Existing and new technology", Division Report ERP/MSL 85-38 (IR).
- + 8 confidential (Cost Recovery) reports.

COMPUTER-AIDED MINERAL PROCESSING



CURRICULUM VITAE

NAME: Daniel Laquitton

DEGREES: Doctorat des Sciences, 1974, Laval University, Quebec
 Diplôme de Docteur en Sciences Physiques, 1970,
 Université de Rennes, France
 Diplôme d'études approfondies en Chimie Minérale, 1969,
 Université de Rennes, France
 Diplôme D'Ingénieur Chimiste, 1968, Ecole Nationale
 Supérieure de Chimie de Rennes, France

EXPERTISE:

Mathematical modelling and computer simulation of mineral processes, software engineering, technology transfer to industry. Also carried-out successful research projects on electron microprobe quantitative analysis and non-destructive analysis of thin films by X-ray fluorescence.

<u>CAREER:</u>	1989 to present	Research Scientist 4, CANMET Adjunct Professor, McGill University
	1988 to present	Adjunct Professor, University of British Columbia and Université Laval
	1984-1989	Research Scientist 3, CANMET
	1978-1984	Research Scientist 2, CANMET
	1975-1977	IBM World Trade postdoctoral fellow, IBM Research Laboratories, San Jose, California.
	1973-1975	Assistant professor, Université Laval.

PROFESSIONAL AFFILIATIONS:

Member	Canadian Institute of Mining and Metallurgy, CIM.
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AWARDS:

Distinguished award, category "scholarly papers", from the Canadian Society for Technical Communication, 1988.

CURRENT RESEARCH AND ACTIVITIES:

- (a) Upgrade and maintenance of simulation software, especially in the area of flowsheet simulation. The latest improvements concern the generalization of the unit modules in order to allow flotation to be simulated in the same flowsheet as comminution and classification. Significant progress is also taking place in the addition of liberation parameters to the various models. (10% of time)
- (b) Negotiations of agreements with industrial partners for the initiation of R&D efforts in the area of AI and process control. These efforts are on the verge of fruition in the form of a major Canadian initiative that would give Canada a long deserved leadership rôle in process control technology for mineral processing plants. (30 % of time)
- (c) Research on dynamic simulation and knowledge extraction from computer records in a flotation circuit. This work is being initiated as a Master's thesis by M.Bilodeau who will have access to the several years of process datafiles recorded at Kidd Creek mines. Techniques of time series analysis and pattern recognition will be applied to extract models and production rules. The techniques will be transferred to industrial users as they become better understood. (10% of time)
- (d) Other duties - administrative duties, staff supervision, management of equipment maintenance and upgrade, answering information requests, completing performance appraisals, requested participation in seminars, drafting and editing of manuals, reports, publications, staffing procedures, etc. (50% of time)

SIGNIFICANT CONTRIBUTIONS:

1. Manual and software for Computer Aided Mineral Processing

A comprehensive manual in 18 separate chapters describing state-of-the art methodology for process evaluation and optimization was published in 1985. It features contributions by leading experts in Canadian universities and mineral processing companies. As such it implements technology transfer from universities to industry through CANMET initiative and leadership. A significant collection of computer programs associated with this methodology evolved from main frame Fortran code to the current MS-DOS executable code registered as "CAMP Software" sold by CANMET. The latest release has been acquired by clients from over a dozen countries around the world.

2. Expert system prototyping in the mineral industry

Since 1986, CANMET has been at the leading-edge of expert system applications in mineral processing through joint projects with industrial partners. Three pilot applications have been completed so-far: 1) an expert system for process diagnosis in a clinker grinding plant (Lafarge, Laval, Unisys, CANMET), 1987; 2) an expert system advisor for operators of a zinc plant (Canadian Electrolytic Zinc, Lavalin, CANMET), 1988; 3) an expert system for on-line data validation in a flotation plant (Kidd Creek, CANMET), 1989. An industrial workshop took place on October 19-20, 1989, to demonstrate the Kidd Creek system on-site and demonstrate computer aided mineral processing techniques.

3. Promotion of a dialogue between CANMET and the mineral processing industry and systematic experimentation of technology transfer techniques

All technologically feasible methods of communication have been employed to establish and maintain close contacts between CANMET and industry in the field of computer aided mineral processing. These include: several workshops, yearly, at various industrial locations, remote computer data links for demonstration and training, numerous seminars and presentations to industrial audiences, a promotional direct mail campaign (1984 Certificate of Excellence by The Canadian Marketing Magazine), a 15 minute videotape production entitled "The computer age in mineral processing", promotional documents and diskettes etc.

REFEREED JOURNAL ARTICLES:

- Ter Heijden, E., Laguitton, D., (1986): Convergence acceleration by the Aitkins delta squared method in a general flowsheet simulator. Canadian Quarterly, Vol. 25, No. 3, p. 211.
- Laguitton, D., Barcados, A., (1987): L'intelligence Artificielle Appliquée au Service de la Minéralurgie. Geos, Vol. 16, No 3, p. 1.
- Laguitton, D., Bilodeau, M., TerHeijden, E., Chassat, P., (1989): Computers add flexibility to aggregate plant design. Pit & Quarry, Edgell Communications, Cleveland, Ohio, August 1989, pp. 136-140.

Laguitton, D., Bilodeau, M., (1989): Development of screen management subroutines compatible with Microsoft Fortran compiler. Accepted for publication in: The Computer Journal, The British Computer Society, London.

REFEREED CONFERENCE PROCEEDINGS:

Laguitton, D., Sirois, L., (1985): Le calcul par ordinateur dans l'industrie Minéralurgique Canadienne en 1984. Proceedings of the International Mineral Processing Conference, Cannes, pp 62-74.

Laguitton, D., Bilodeau, M., (1987): Simulation and Expert Systems. Computer Aided Mineral Processing: Proceedings of the Copper87 Conference, Vina del Mar, Chile, Vol.2.

Laguitton, D., (1988): Expert system prototyping in mineral processing. Proceedings of the plenary session at the APCOMIN'88 Symposium, Santiago.

Laguitton, D., Bilodeau, M., Ghibu, C., Boulanger, J.P., Farner, I., Dupuis, D., (1989): Expert system advisor for operators of a zinc leaching plant. Proceedings of the 6th Symposium on Automation in Mining, Mineral and Metal Processing Industries, (IFAC), Buenos-Aires.

Laguitton, D., Leung, J., (1989): 15 years of progress in material balance computation. Insert the diskette and type "MATBAL". Proceedings of the symposium AIPAC'89, Advanced Information Processing in Automatic Control, (IFAC), Nancy.

BOOKS AND SPECIAL PUBLICATIONS:

Laguitton, D., Editor: Laguitton, D., (1985): Summary. The SPOC Manual - Chapter 1, CANMET Special Publication SP 85-1/1E, 14 pages.

Smith, H.W., Editor: Laguitton, D., (1985): Sampling Methodology. The SPOC Manual - Chapter 2, CANMET Special Publication SP 85-1/2E, 26 pages.

Smith, H.W., Burroughs, D., Laguitton, D., Editor: Laguitton, D., (1985): SAMBA Computer Program. The SPOC Manual - Chapter 2.1, CANMET Special Publication SP 85-1/2.1E, 51 pages.

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- Laguitton, D., Hodouin, D., Editor: Laguitton, D., Material Balance. The SPOC Manual - Chapter 3, CANMET Special Publication Sp 85-1/3E, 22 pages.
- Hodouin, D., Flament, F., Editor: Laguitton, D., (1985): BILMAT Computer Program, BILMAT - Computer Program. The SPOC Manual - Chapter 3.1, CANMET Special Publication Sp 85-1/3.1E, 141 pages.
- Laguitton, D., Editor: Laguitton, D., (1985): MATBAL Computer Program. The SPOC Manual - Chapter 3.2, CANMET Special Publication SP 85-1/3.2E, 58 pages.
- Finch, J.A., Laplante, A., Leung, J., Editor: Laguitton, D., (1985): Modelling and Simulation, Modelling and Simulation Methodology for Ore and Coal Processes. The SPOC Manual - Chapter 4, CANMET Special Publication SP 85-1/4E, 90 pages.
- Spring, R., Larsen, C., Mular, A., Editor: Laguitton, D., (1985): Documented Application of the Kinetic Model. The SPOC Manual - Chapter 4.1, CANMET Special Publication SP 85-1/4.1E, 35 pages.
- Mular, A., Editor: Laguitton, D., (1985): Comminution and Flotation. The SPOC Manual - Chapter 5: Unit Models (Part A), Unit Models and FORTRAN Simulators of Ore and Coal Process Equipment, CANMET Special Publication SP 85-1/5E, 53 pages.
- Plitt, L.R., Flintoff, B.C., Editor: Laguitton, D., (1985): Classification and Coal Processing. The SPOC Manual - Chapter 5.1: Unit Models (Part B), Unit Models and FORTRAN Simulators of Ore and Coal Process Equipment, CANMET Special Publication SP 85-1/5.1E, 132 pages.
- Laguitton, D., Flament, F., Wilson, J., Pilgrim, R., Cameron, W., Feader, W., Beeckmans, J., Editor: Laguitton, D., (1985): Miscellaneous. The SPOC Manual - Chapter 5.2: Unit Models (Part C), Unit Models and FORTRAN Simulators of Ore and Coal Process Equipment, CANMET Special Publication Sp 85-1/5.2E, 63 pages.
- Flament, F., Laguitton, D., Terheijden, E., Chassat, P., Editor: Laguitton, D., (1985): Plant Simulators, Plant Simulators for Mineral Dressing. The SPOC Manual - Chapter 6, CANMET Special Publication SP 85-1/6E, 201 pages.

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- Seguin, F., Leung, J., Flament, F., Laguitton, D., Editor: Laguitton, D., (1985): STAMP Computer Program. The SPOC Manual - Chapter 7.1, CANMET Special Publication SP 85-1/7.1E, 56 pages.
- Laguitton, D., Leung, J., Gupta, V.K., Hodouin, D., Spring, R., Editor: Laguitton, D., (1985): FINDBS Computer Program. The SPOC Manual - Chapter 7.2, CANMET Special Publication SP 85-1/7.2E, 58 pages.
- Laguitton, D., Leung, J., Flament, F., Hodouin, D., Spring, R., Editor: Laguitton, D., (1985): RTD and MIXERS Computer Program. The SPOC Manual - Chapter 7.3, CANMET Special Publication Sp 85-1/7.3E, 78 pages.
- Laguitton, D., Leung, J., Editor: Laguitton, D., (1985): Utility Programs. The SPOC Manual - Chapter 8, CANMET Special Publication Sp 85-1/8E, 25 pages.
- Laguitton, D., Editor, (1987): Proceeding of the CANMET Symposium on Expert Systems in the Mineral Industry. CANMET SP 87-4E and F, Ottawa.

OTHER CONFERENCE PROCEEDINGS:

- Laguitton, D., (1985): SPOC Project Annual Report 1984-1985. A First Generation of Software for the Canadian Mineral Processors, Proceedings of the 17th Annual Canadian Mineral Processors Meeting, Ottawa.
- Laguitton, D., (1987): New computer technology finds applications in mineral processing R&D at CANMET. Proceedings of the 19th CMP annual meeting, Ottawa.
- Laguitton, D., (1988): Expert Systems in Mineral Processing. Proceedings of the 20th Conference of the Canadian Mineral Processors Division of the CIM, Ottawa.
- Laguitton, D., Pilgrim, R., (1988): the Rôle and Contribution of CANMET. Computer Aided Mineral Processing, Proceedings of the First Canadian Conference on Computer Applications in the Mineral Industry, Quebec City, p. 127.

Flament, F., Hodouin, D., Vanderstichelen, J., Laguitton, D., (1988): Prototyping and Expert System for the Trouble-shooting of a Clinker Grinding Mill. Proceedings of the Conference on Artificial Intelligence in Minerals and Materials Technology, University of Alabama, Tuscaloosa.

Flament, F., Hodouin, D., Vanderstichelen, J., Laguitton, D., (1988): the KEE Expert System Shell. Tool Assessment in Expert System Prototyping, Proceedings of the First Canadian Conference on Computer Applications in the Mineral Industry, Quebec City, p. 565.

Burroughs, M., Carriere, J., Leung, J., Laguitton, D., (1989): An expert system to improve reliability of assay information in a flotation plant. Proceedings of the 21st Canadian Mineral Processors, Ottawa.

Laguitton, D., Leung, J., (1989): Advances in expert systems applications in mineral processing. Proceedings of the annual meeting of the Metallurgical Society of CIM, Halifax.

PARTICIPATION IN NATIONAL/INTERNATIONAL MEETINGS (other than oral presentations):

1985 International Scientific Committee, International Mineral Processing Conference, Cannes. (Substitute delegate)

1988 International Scientific Committee, International Mineral Processing Conference, Stockholm. (Substitute delegate)

Mineral Processing Software Technology Mission to Chile, sponsored by the Department of External Affairs.

1989 Advanced Technology Mission to Brazil, sponsored by the Department of External Affairs.

PYROMETALLURGY

CURRICULUM VITAE

NAME: J.M. Skeaff

DEGREES: B.A.Sc. 1964, University of Toronto
M.A.Sc. 1966, University of Toronto
Ph.D. 1971, University of Toronto

EXPERTISE:

Pyrometallurgy, high temperature processing, thermo-chemistry.

<u>CAREER:</u>	1982 - present	Head, Pyrometallurgy Section, EML, MSL, CANMET
	1979 - present	Research Scientist 2, CANMET
	1974 - 1979	Research Scientist 1, CANMET
	1973 - 1974	Research Associate, Rensselaer Polytechnique Institute, Troy, N.Y., U.S.A.
	1971 - 1973	Research Assistant, Metallurgisk Institutt, Technical University of Norway, Trondheim, Norway.

PROFESSIONAL AFFILIATIONS:

American Institute of Mining, Metallurgical and Petroleum Engineers - Minerals, Metals and Materials Society (TMS).

AWARDS:

U.S. Patent under Public Service Inventions Regulations.

CURRENT RESEARCH AND OTHER ACTIVITIES:

- (a) Thermochemistry of Arsenides and Arsenates: A furnace control and data acquisition system has been designed, developed and installed and will be used to determine the thermochemical properties of the arsenates of lead and nickel.
- (b) Sensor Development: A shared cost proposal is being prepared for the development of a PbO sensor for use in lead blast furnace slags.
- (c) Smelting Studies: The response to a proposal for the investigation of the reduction of a refractory metal oxide by a reactive metal is pending.

- (d) Section head activities, including consultations, proposal preparation and contracts.
- (e) Refereeing papers, reviewing manuscripts and grant proposals.

SIGNIFICANT CONTRIBUTIONS:

1. As Head, Pyrometallurgy Section, gives focus and direction to MSL's R&D in pyrometallurgy which includes the fields of arsenic compound thermochemistry, limestone evaluation for use in fluidized bed combustion, plasma technology, smelting studies and sensor development.
2. Thermochemical properties of arsenides and arsenates at elevated temperatures to enable the calculation of the behaviour of arsenic-bearing systems under pyrometallurgical conditions.
3. Project leader on industrial applications of plasma technology to pyrometallurgical and energy related processes.
4. Smelting studies on recovery of gold and silver from zinc pressure leach residues with Hudson Bay Mining and Smelting, production of antimony from stibnite concentrate with Durham Resources, recovery of molybdenum as Fe-Mo from spent catalyst with Sharper Alloys.
5. Spearheaded initiative for project on development of chemical sensors for SO_2 - SO_3 and As_2O_3 in gases and metals in mattes, slags and liquid metals.

REFEREED JOURNAL ARTICLES:

- Skeaff, J.M., Mainwaring, P.R., & Speelman, J.L. (1985): Thermochemical Arsenide-Oxide Equilibria in the System Ni-As-O Determined Electrochemically Between 438° and 866°C. Can. Metall. Quarterly 24(4), 349-362.
- Skeaff, J.M. (1989): Thermochemical Arsenide-Oxide Equilibria in the System Fe-As-O Determined Electrochemically Between 317° and 536°C. Can. Metall. Quarterly 28(2), 117-126.
- Kirchnerova, J., Bale, C.W., and Skeaff, J.M. (1989): Ag- β - Al_2O_3 Solid Electrolyte for Sensing Arsine, AsH_3 , Sensors and Actuators (in press).

CONFERENCE PROCEEDINGS:

Skeaff, J.M., Mainwaring, P.R., & Speelman, J.L. (1985): Electrochemical Determination of Arsenide-Oxide Equilibria in the System Ni-As-O Between 438° and 866°C. Proc. TMS-AIME Symposium Complex Sulphides, San Diego, Nov. 10-13/85 (A.D. Zunkel, R.S. Boorman, A.E. Morris & R.J. Wesley, eds.)

Kirchnerova, J., Bale, C.W., and Skeaff, J.M. (1986): Silver beta-Alumina as a Sensor for Gaseous Arsenic Oxides, Proc. Second International Symposium on Chemical Sensors, Bordeaux, France, July 7-10/86.

Skeaff, J.M., Craigen, W.J.S., & Barlin, B. (1989): Technical and Economic Assessment of Gold and Silver Recovery from Sherritt Gordon/HBMS Zinc Pressure Leach Residue by a Pyrometallurgical Method, Proc. IPMI-AIME Symposium Precious Metals '89, Las Vegas, Feb. 27- Mar. 2/89 (M.C. Jha and S.D. Hill, eds.)

PATENTS:

Kirchnerova, J., Skeaff, J.M. & Bale, C.W. (1989): Solid State Arsenic Probe for Use in Pyrometallurgical Processes, U.S. Patent no. 4,842,698, June 27/89.

REPORTS:

Skeaff, J.M. (1986): Smelting of Durham Resources Stibnite Concentrate to Produce Metallic Antimony. Mineral Sciences Laboratories Division Report 86-16 (CR).

Shimano, D.Y. & Skeaff, J.M. (1988): Dewatering of a Calcium Hydroxide Slurry. Mineral Sciences Laboratories Division Report 88-7 (CR).

Skeaff, J.M., & Craigen, W.J.S. (1989): Gold and Silver Recovery from Sherritt Gordon/HBMS Zinc Pressure Leach Residue by a Pyrometallurgical Method: I. Results of Preliminary Tests, Mineral Sciences Laboratories Division Report 86-1 (CF).

ORAL PRESENTATIONS:

Skeaff, J.M., Mainwaring, P.R., & Speelman, J.L.: Electrochemical Determination of Arsenide-Oxide Equilibria in the System Ni-As-O Between 438° and 866°C. 12th Canadian Metals Chemistry Conference, Kingston, June 11-13/85.

Skeaff, J.M., Mainwaring, P.R., & Speelman, J.L.: Electrochemical Determination of Arsenide-Oxide Equilibria in the System Ni-As-O Between 438° and 866°C. TMS-AIME Symposium Complex Sulphides, San Diego, Nov. 10-13/85.

Skeaff, J.M.: Thermochemical Arsenide-Oxide Equilibria in the System Fe-As-O Determined Electrochemically Between 317° and 536°C. 15th Canadian Metals Chemistry Conference, Kingston, June 8-10/88.

Skeaff, J.M.: Thermochemical Arsenide-Oxide Equilibria in the System Fe-As-O Determined Electrochemically Between 317° and 536°C. CIM Conference of Metallurgists, Montreal, Aug 28-31/88.

Skeaff, J.M., Craigen, W.J.S., & Barlin, B. (1989): Technical and Economic Assessment of Gold and Silver Recovery from Sherritt Gordon/HBMS Zinc Pressure Leach Residue by a Pyrometallurgical Method, IPMI-AIME Symposium Precious Metals '89, Las Vegas, Feb. 27-Mar. 2/89.

SCIENTIFIC AUTHORITY/ADVISOR FOR IRAP AND NSERC:

DC plasma arc furnace - INCO Port Colbourne,
Study of flash smelting of bulk Cu/Ni concentrate - INCO/UBC,
Treatment of copper-silver chlorides - U of T/Queen's/Royal
Canadian Mint

HYDROMETALLURGY



CURRICULUM VITAE

NAME: J.E. Dutrizac

DEGREES: Ph.D., 1967, University of Toronto
M.A.Sc., 1964, University of Toronto
B.A.Sc., 1963, University of Toronto

EXPERTISE:

Extractive metallurgist with experience in both hydrometallurgy and pyrometallurgy as well as a continuing involvement in the field of applied mineralogy. Expertise in the ferric ion leaching of sulphides such as chalcopyrite, galena and sphalerite, and in the related field of iron precipitation and control. Work has involved jarosite precipitation and hematite formation. Considerable experience in the processing of zinc, the electrorefining of copper and the hydrometallurgical treatment of lead. Considerable involvement in the treatment of metallurgical effluents to control arsenic and thiosalts. Some experience and expertise in the processing of zirconium, titanium and magnesium. In all areas, the processing aspects are related to the fundamental chemical properties of the system, and efforts commonly are employed to combine chemical and mineralogical techniques.

CAREER:

1976-present	Research Scientist and Head, Metallurgical Chemistry Section, CANMET
1968-1976	Research Scientist, CANMET
1967-1968	Research Scientist, Noranda Research Centre

PROFESSIONAL AFFILIATIONS:

Fellow	Canadian Institute of Mining and Metallurgy
Member	Canadian Institute of Mining and Metallurgy
Member	Chemical Institute of Canada
Member	TMS Pb-Zn-Sn Committee
Co-organizer	TMS Lead-Zinc '90 Symposium

Member	CIM Historical Metallurgy Committee
Co-chairman	1991 Conference of Metallurgists
Publicity chairman	20th Annual Hydrometallurgical Meeting
Secretary	Copper 91-Cobre 91 Conference
Editorial Board member	Hydrometallurgy
Editorial Board member	Progress in Extractive Metallurgy

PROFESSIONAL AFFILIATIONS (Past Five Years):

- | | |
|-------------|---|
| 1984 | - President of the Metallurgical Society of CIM |
| | - Member Hydrometallurgy Section of CIM |
| | - Member TMS-AIME Publications Committee |
| 1985 | - Member TMS-AIME Publications Committee |
| | - Member CIM Publications Committee |
| | - Member Plummer Metal Committee of CICHÉ |
| | - NSERC Grant Selection Committee |
| 1986 | - Co-chairman of the International Symposium on Iron Control in Hydrometallurgy |
| | - Member TMS and CIM Publication Committees |
| | - NSERC Grant Selection Committee |
| 1987 | - Member NSERC Grant Selection Committee |
| | - Co-ordinator for the Engineering Centennial in Canada, Montreal |
| 1988 | - Member NSERC Grant Selection Committee |
| | - Advisory Committee member of the International Symposium on the Production and Processing of Fine Particles |

- Invited Session Chairman of the Electrotechnologies for the Metal and Chemical Industries Conference
- Member NSERC Strategic Grants Revision Committee
- Member of the CIM Light Metals Committee

AWARDS:

- 1989 Silver Medal of the Metallurgical Society of the Canadian Institute of Mining and Metallurgy (CIM)
- 1989 CIM Best Paper Award
- 1988 Consolidated Gold Fields Silver Metal awarded by the Institution of Mining and Metallurgy, London
- 1988 Elected Fellow of CIM
- 1985 CIM Best Paper Award
- 1984 Sherriitt Hydrometallurgy Award

CURRENT RESEARCH AND OTHER ACTIVITIES

- (a) Zinc processing: Co-ordinates the Canadian Zinc Producers and conducts research related to zinc roasting and leaching, solution purification and impurity removal. This project involves all Canadian zinc producers as well as several university researchers (15% of time).
- (b) Copper refining: Co-ordinates the Copper Refinery Group of six major copper refiners, and also conducts research related to impurity deportment in copper anodes and anode slimes. Current research is focussed on the behaviour of silicates and the platinum group elements (15% of time).
- (c) Chloride metallurgy: Leaching studies on sulphide minerals continue with emphasis on the ferric sulphate leaching of galena and the generation and control of trace SO_4 in the ferric chloride leaching of pyritic bulk concentrates (15% of time).
- (d) Effluent control: An involvement with thiosalts continues through the BMS task force on thiosalt effluents. Work on arsenic control continues, and studies on the precipitation of divalent base metal arsenates are in progress. The mechanism of arsenic incorporation in amorphous iron

arsenates is receiving attention and a high temperature scorodite precipitation process is being examined (15% of time).

- (e) Project monitoring: As project leader for the Copper Refining Group and the Canadian Zinc Processors, is involved in developing co-operative research projects, in evaluating proposals and in organizing review meetings. Each project has a CANMET commitment of ~6 py, as well as extensive industrial participation. Associated with this activity is the monitoring and evaluation of various CANMET or DS&S contracts (10% of time).
- (f) Administration: As Head of the Metallurgical Chemistry Section, is involved in developing research efforts, monitoring work, reviewing manuscripts as well as dealing with a host of administrative activities. An associated part of this activity involves the review of contract proposals and participation in various meetings related to scientific activities or general CANMET administration (20% of time).
- (g) Professional activities: These include involvement in professional societies, the organization of conferences and symposia, review of manuscripts and conference attendance. An associated part of this activity is support of NSERC review procedures via various committees (10% of time).

SIGNIFICANT CONTRIBUTIONS

1. Ferric ion leaching

The use of ferric chloride or ferric sulphate solutions for leaching sulphide minerals holds considerable commercial promise as elemental sulphur is the principal sulphidic reaction product. A large number of experimental programs has been carried out to define the parameters affecting the leaching of several sulphide minerals and to shed some light on the complex kinetics involved. The effect of the elemental sulphur reaction product on the leaching kinetics has been clarified and the relative importance of minor SO_4 production assessed. An extensive program was carried out to help develop a ferric chloride leach process for galena concentrates; this program was ultimately expanded to include the electrolytic recovery of lead from the PbCl_2 intermediate product. The leaching studies have also contributed to the development of the CANMET Ferric Chloride Leach Process for pyritic bulk concentrates. The studies on the ferric ion leaching of sulphides have resulted in several papers and presentations, as well as

frequent contacts with international experts active in the field.

2. Iron precipitation

Iron is a common impurity in most metallurgical circuits, and therefore, the precipitation of iron in a readily filterable form is of great importance in hydrometallurgy. Extensive experimental work has been carried out at CANMET to elucidate the conditions affecting the precipitation of jarosite-type compounds and to identify the nature and limits of impurity incorporation in this important class of minerals. A notable achievement was the use of NMR methods to confirm the presence of hydronium ion in jarosite-type compounds. The conversion of jarosites to more compact products such as hematite is also being pursued, and the conditions affecting the conversion reaction have been elucidated. Because the conversion reaction proceeds only at $>220^{\circ}\text{C}$, it was concluded that jarosite formation-hematite conversion would not be as commercially attractive as the direct formation of Fe_2O_3 from the processing solution. Consequently, the most recent efforts have been directed towards the definition of the conditions leading to the precipitation of a clean hematite directly from a ferric ion solution. The work on iron precipitation is of considerable concern to the zinc industry and working arrangements have been established with several Canadian, European and Japanese zinc producers.

3. Zinc processing

Silver is commonly present in modest concentrations in zinc concentrates, and silver recovery can add to the overall economics of zinc processing. Numerous studies have been carried out to define the nature of silver in various zinc plant intermediate products and to use this information to elucidate the complex reactions which occur. It has been shown that silver metal predominates in roaster calcine but that silver sulphate and silver-bearing silicates also occur. In neutral leaching, most of the silver is converted to Ag_2S whereas in hot acid leaching AgCl and Ag -bearing jarosites are formed. The purification of zinc solutions and, of course, the iron control problem, also have been investigated. In conjunction with the industry, a flotation process for silver and gold recovery has been developed, and a Canadian zinc producers working group has been established.

4. Copper refining

Most of the world's copper is electrorefined both to give high purity metal and to recover valuable by-products. Studies have been carried out to identify the mineral and chemical forms of various impurities in copper anodes and the resulting anode slimes. The behaviour of silver and nickel has been well documented. Despite the <0.1 mg/L Ag concentrations in the electrolyte, it was shown that silver was very mobile in the refining circuit and that several new silver phases were produced. Significantly, AgCl is not detected. Although refractory nickel compounds are present, most of the nickel occurs in solid solution in the copper and dissolves during electrorefining. Important observations on the behaviour of gold and tellurium also have been made. A working group of six copper refineries has been established that is examining anode passivation, solution purification, impurity recovery and refinery control.

5. Effluent treatment

Effluent treatment is becoming increasingly important in the metallurgical industry, and major studies have been launched on thiosalts and arsenic. A project on the characterization and control of thiosalt effluents was established that developed new analytical procedures and clarified how thiosalts were generated in the milling circuit. Several thiosalt destruction processes were evaluated and many authoritative reports were prepared. Arsenic control in processing effluents is also a concern, and new high-sensitivity analytical procedures for low arsenic concentrations were developed. Also, the incorporation of arsenic in various types of iron residue has been examined. Notable was the differentiation between amorphous iron arsenate and crystalline scorodite, $\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$, as the latter compound is considerably less soluble.

REFEREED JOURNAL PUBLICATIONS:

- Dutrizac, J.E. and Chen, T.T. (1984): A mineralogical study of the jarosite phase formed during the autoclave leaching of zinc concentrate. Canada. Metal. Quart. 23(2), 147-157.
- Rolia, E. and Dutrizac, J.E. (1984): The determination of free acid in zinc processing solutions. Canada. Metal. Quart., 23(2), 159-167.

- Dutrizac, J.E. and O'Reilly, J.B. (1984): The origins of zinc and brass. CIM Bull., 77(869), 69-73.
- Lenchev, A. and Dutrizac, J.E. (1984): The behaviour of silver during the roasting of zinc concentrate. Canada. Metal. Quart., 23(3), 287-294.
- Chen, T.T., Dutrizac, J.E. and Haque, K.E. (1984): Preliminary study of the relative transparency of minerals to microwave radiation. Canada. Metal. Quart., 23(3), 349-355.
- Wasserlauf, M. and Dutrizac, J.E. (1984): CANMET's project on the chemistry, generation and treatment of thiosalts in milling effluents. Canada. Metal. Quart., 23(3) 259-270.
- Jambor, J.L. and Dutrizac, J.E. (1985): Synthesis of beaverite. Canada. Mineral., 23(1), 47-51.
- Dinardo, O. and Dutrizac, J.E. (1985): The solubility of silver chloride in ferric chloride leaching media. Hydrometallurgy, 13, 345-363.
- Tan, L.K. and Dutrizac, J.E. (1985): The determination of arsenic (III) and arsenic (V) in ferric chloride-hydrochloric acid leaching media by ion chromatography. Anal. Chem., 57, 1027-1032.
- Dutrizac, J.E. and O'Reilly, J.B. (1985): The first cyanide leaching plants in Canada. CIM Bull., 78(876), 75-76.
- Townsend, M.G., Longworth, G. and Dutrizac, J.E. (1985): Linear-chain antiferromagnetism in FeOH.SO_4 and FeOH.CrO_4 . J. Phys. C: Solid-State Phys., 31(5), 2966-2973.
- Dutrizac, J.E., Chen, T.T. and Jambor, J.L. (1985): Mineralogical changes occurring during the ferric ion leaching of bornite. Metal. Trans., 16B, 679-693.
- Tan, L.K. and Dutrizac, J.E. (1985): Determination of arsenic (V) and arsenic (III) in ferric sulfate - sulfuric acid leaching media by ion chromatography. Anal. Chem., 57, 2615-2626.
- Dutrizac, J.E. and O'Reilly, J.B. (1985): Further observations on Canada's first cyanide leaching plant. CIM Bull., 78(880), 70-71.
- Dutrizac, J.E. (1985): The reaction of zirconium with selenium vapour. Canada. Metal. Quart., 24(4), 375-376.

- Dutrizac, J.E. (1986): The dissolution of galena in ferric chloride media. *Metal. Trans.*, 17B, 5-17.
- Dutrizac, J.E. and Jambor, J.L. (1986): Host minerals for the gallium-germanium ores of the Apex Mine, Utah. *Econ. Geol.*, 81, 946-950.
- Ripmeester, J.A., Radcliffe, C.I., Dutrizac, J.E. and Jambor, J.L. (1986): Hydronium ion in the alunite-jarosite group. *Canada. Mineral.*, 24, 435-447.
- Tan, L.K. and Dutrizac, J.E. (1986): Simultaneous determination of arsenic (III) and arsenic (V) in metallurgical leaching media by ion chromatography with electrochemical and conductivity detectors. *Anal. Chem.*, 58, 1383-1389.
- Dutrizac, J.E. (1987): The dissolution of silver chloride in ferric chloride-hydrochloric acid media. *Trans. I.M.M.*, 96, C79-C86.
- Dutrizac, J.E. and Jambor, J.L. (1987): Behaviour of cesium and lithium during the precipitation of jarosite-type compounds. *Hydrometallurgy*, 17, 251-265.
- Tan, L.K. and Dutrizac, J.E. (1987): Simultaneous determination of arsenic (III) and arsenic (V) in metallurgical processing media by ion chromatography. *J. Chromatography*, 405, 247-261.
- Dutrizac, J.E. and Jambor, J.L. (1987): The behaviour of arsenic during jarosite precipitation: Arsenic precipitation at 97°C from sulphate or chloride media. *Canada. Metal. Quart.*, 26(2), 91-101.
- Dutrizac, J.E., Jambor, J.L. and Chen, T.T. (1987): The behaviour of arsenic during jarosite precipitation: Reactions at 150°C and the mechanism of arsenic precipitation. *Canada. Metal. Quart.*, 26(2), 103-115.
- Dutrizac, J.E. and Chen, T.T. (1987): Mineralogical characterization of the residues of the two-stage oxygen pressure leaching of a pyritic Zn-Pb-Cu-Ag concentrate with SO₂ reduction of the jarosite fraction. *Canada. Metal. Quart.*, 26(3), 189-205.
- Dutrizac, J.E. and Chen, T.T. (1987): A mineralogical study of the phases formed during the CuSO₄-H₂SO₄-O₂ leaching of nickel-copper matte. *Canada. Metal. Quart.*, 26(4), 265-276.

- Dutrizac, J.E. and Jambor, J.L. (1987): The behaviour of silver during jarosite precipitation. Trans. I.M.M., 96, C206-C217.
- Dutrizac, J.E. and Jambor, J.L. (1988): The synthesis of crystalline scorodite, $\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$. Hydrometallurgy, 19, 377-384.
- MacKinnon, D.J., Dutrizac, J.E., Brannen, J.M. and Hardy, D.J. (1988): The behaviour of thiourea and flotation reagents in zinc electrowinning circuits. Metal. Trans., 19B, 187-199.
- Jambor, J.L. and Dutrizac, J.E. (1988): Synthesis of the ferric analog of the ferrous-ferric phosphate, giniite. Neues. Jhr. Mineral. Monat., 159(1), 51-58.
- Chen, T.T. and Dutrizac, J.E. (1988): Application of electron microscopy to the electrorefining of copper. Scanning Microscopy, 2(2), 735-746.
- Chen, T.T. and Dutrizac, J.E. (1988): Mineralogical characterization of anode slimes: Part 1 - Anode copper from Inco's Copper Cliff copper refinery. Canada. Metal. Quart., 87(2), 91-96.
- Chen, T.T. and Dutrizac, J.E. (1988): Mineralogical characterization of anode slimes: Part 2 - Raw anode slimes from Inco's Copper Cliff copper refinery. Canada. Metal. Quart., 87(2), 97-105.
- Chen, T.T. and Dutrizac, J.E. (1988): Mineralogical characterization of anode slimes: Part 3 - Sulphation reactor slimes from Inco's Copper Cliff copper refinery. Canada. Metal. Quart., 87(2), 107-116.
- Dutrizac, J.E. (1988): Still further observations on Canada's first cyanide leaching plant: Early Ontario operations. CIM Bull., 81(911), 157-161.
- Wasserlauf, M., Condy, A.A., Wheeland, K. and Dutrizac, J.E. (1988): Techno-economic evaluation of thiosalt treatment processes. CIM Bull., 81(909), 82-86.
- Chen, T.T. and Dutrizac, J.E. (1988): Mineralogical characterization of silver flotation concentrates made from zinc neutral leach residues. Metal. Trans., 19B, 803-817.
- Dutrizac, J.E. and Sunstrum, J.B. (1988): Early Canadian lead smelters. CIM Bull., 81(920), 75-77.

- Dutrizac, J.E. and Chen, T.T. (1988): Mineralogical characterization of the silver flotation concentrates made at Vieille-Montagne, Balen, Belgium. Trans. I.M.M., 97, C180-C190.
- Chen, T.T. and Dutrizac, J.E. (1989): A mineralogical study of the deportment and reaction of silver during copper electrorefining. Metal. Trans., 20B, 345-361.
- Dutrizac, J.E. (1989): The leaching of galena in cupric chloride media. Metal. Trans., 20B, 475-483.
- Chen, T.T. and Dutrizac, J.E. (1989): Mineralogical characterization of anode slimes: Part 4 - Copper-nickel-antimony oxide ("kupferglimmer") in CCR anodes and anode slimes. Can. Metal. Quart. (in press).
- Dutrizac, J.E. (1989): Sulphate control in chloride leaching processes. Hydrometallurgy (in press).
- Chen, T.T. and Dutrizac, J.E. (1989): Mineralogical characterization of anode slimes: Part 5 - Nickel-rich copper anodes from the CCR division of Noranda Minerals Inc. Can. Metal. Quart. (in press).
- Dutrizac, J.E. (1989): Elemental sulphur formation during the ferric chloride leaching of chalcopyrite. Hydrometallurgy (in press).

REFEREED CONFERENCE PROCEEDINGS:

- Dutrizac, J.E. and Morrison, R.M. (1984): The leaching of some arsenide and antimonide minerals in ferric chloride media. In Hydrometallurgical Process Fundamentals, (Bautista, R.G. Ed.), Plenum Publishing Corp., 77-112.
- Dutrizac, J.E. (1984): The behaviour of impurities during jarosite precipitation. In Hydrometallurgical Process Fundamentals, (Bautista, R.G. Ed.), Plenum Publishing Corp., 125-170.
- Dutrizac, J.E. and Jambor, J.L. (1985): Formation and characterization of argentojarosite and plumbojarosite and their relevance to metallurgical processing. In Applied Mineralogy, (Park, W.C. et al. Eds.), TMS-AIME, 507-530.
- Dutrizac, J.E. (1985): Silver behaviour in hydrometallurgical zinc circuits. In Zinc '85: Proc. Int. Symp. Ext. Metal. Zinc, (Tozawa, K. Ed.), Min. Metal. Inst. Japan, Chapter 24, 707-727.

- Dutrizac, J.E. and Jambor, J.L. (1985): Impurity control during jarosite formation. In Impurity Control and Disposal: Proc. 15th Annual Hydrometallurgical Meeting, (Oliver, A.J. Ed.), CIM, Paper 23, 24 pp.
- Dutrizac, J.E. (1986): Recent advances in the leaching of sulphides and in the precipitation of iron. In the Proceedings of MINTEK 50, (Haughton, L.F. Ed.), The Council for Mineral Technology, 39-62.
- Dutrizac, J.E. (1987): Kinetics of the ferric chloride leaching of silver, antimonial silver and silver chloride. In Hydrometallurgical Reactor Design and Kinetics, (Bautista, R.G., Wesely, R.J. and Warren, G.W. Eds.), TMS-AIME, 1-21.
- Chen, T.T. and Dutrizac, J.E. (1987): Mineralogical characterization of anode slimes from the Kidd Creek copper refinery. In Electrowinning and Winning of Copper, (Hoffmann, J.E., Bautista, R.G., Ettel, V.A., Kudryk, V. and Wesely, R.J., Eds.), TMS-AIME, 499-525.
- Dutrizac, J.E. (1987): An overview of iron precipitation in hydrometallurgy. In Crystallization and Precipitation, (Strathdee, G.L., Klein, M.O. and Melis, L.A., Eds.), Pergamon Press, 259-283.
- Dutrizac, J.E. and Chen, T.T. (1988): A mineralogical comparison of the anode slimes from three Canadian copper refineries. In Copper '87, (Cooper, W.C., Lagos, G.E. and Ugarte, G. Eds.), University of Chile, Vol. 3, 467-486.
- Dutrizac, J.E. and Chen, T.T. (1989): Mineralogical characterization of silver flotation concentrates made from zinc leach residues. In Precious and Rare Metal Technologies, (Torma, A.E. and Gundiler, I.H. Eds.), Elsevier, 95-112.
- Dutrizac, J.E. (1989): The hydrothermal conversion of jarosite-type compounds to hematite. In Productivity and Technology in the Metallurgical Industries, (Koch, M. and Taylor, J.C. Eds.), TMS, 587-612.
- Ozberk, E., Dutrizac, J.E. and Minto, R. (1989): Lead-chloride electrolysis and the conceptual design of a cell. In Proceedings of Extraction Metallurgy '89, IMM, 861-884.
- Chen, T.T. and Dutrizac, J.E. (1989): Behaviour of silver during the electrowinning of copper. In Precious Metals 1989, (Harris, B. Ed.), Inter. Precious Metals. Inst., 425.

BOOKS:

Dutrizac, J.E. and Monhemius, A.J. (1986): Iron Control in Hydrometallurgy. Ellis Horwood Limited, Chichester, England, 794 pp.

ORAL PRESENTATIONS:

Recent advances in the leaching of sulphides and the precipitation of iron. Invited keynote speaker at MINTEK '85, Johannesburg, South Africa, March 26-30, 1984.

Formation and characterization of argentojarosite and plumbojarosite and their relevance to metallurgical processing. 2nd International Congress on Applied Mineralogy, Los Angeles, February 22-25, 1984.

An overview of iron precipitation technologies and the incorporation of divalent ions in jarosite-type compounds. 113th TMS-AIME Annual Meeting, Los Angeles, February 25-March 1, 1984.

Iron precipitation in hydrometallurgical systems. Seminar presented at the Canada/EEC Seminar on Complex Sulphide Ores, Brussels, Belgium, May 15, 1984.

The dissolution of galena in ferric chloride media. 114th TMS-AIME Annual Meeting, New York, February 24-28, 1985.

Impurity control during jarosite precipitation. 15th Annual Hydrometallurgical Meeting, Vancouver, August 18-21, 1985.

Silver behaviour in hydrometallurgical zinc circuits. Zinc '85, Tokyo, Japan, October 14-16, 1985.

Silver control in zinc processing. Invited seminar given at Kyoto University, Kyoto, Japan, October 23, 1985.

Iron control in processing circuits. Canada/EEC Seminar on the Processing of Complex Minerals, Ottawa, May 13, 1985.

Current research activities at CANMET. Invited Seminar presented at the USBM, Reno, Nevada, January 27, 1986.

Leaching of silver minerals. Invited Seminar given at Boliden Metall, Sweden, April 21, 1986.

Ferric chloride leaching of silver, antimonian silver and silver chloride. 25th Annual Conference of Metallurgists, Toronto, August 17-20, 1986.

The behaviour of silver in zinc processing. Seminar presented at Cominco Ltd., Trail, B.C., September 17, 1986.

Mineralogical characterization of the residue from the two-stage pressure leaching of bulk concentrates. Seminar presented at Sherritt Gordon Ltd., Fort Saskatchewan, Alberta, September 20, 1986.

The mineralogical characterization of anode slimes from the Kidd Creek copper refinery. TMS Symposium on the Electrorefining and Winning of Copper, Denver, February 22-26, 1987.

An overview of iron precipitation in hydrometallurgy. Invited Overview Paper given at the 17th Annual Hydrometallurgical Meeting, Saskatoon, October 4-8, 1987.

A mineralogical comparison of the anode slimes from three Canadian copper refineries. International Symposium Copper 87, Vina del Mar, Chile, December 3, 1987.

Iron precipitation and iron residue stabilization. Invited Presentation to the Jarosite R&D Group, Odda, Norway, September 17, 1987.

Mineralogical characterization of silver flotation concentrates made from zinc leach residues. Symposium on Precious and Rare Metals, Albuquerque, April 6, 1988.

The CANMET ferric chloride leach process - an overview. CANMET/EEC Seminar on Complex Sulphide Ores, Luxembourg, November 29, 1988.

The hydrothermal conversion of jarosite-type compounds to hematite - A potential process for the zinc industry. CANMET/EEC Seminar on Complex Sulphide Ores, Luxembourg, November 29, 1988.

Iron control. Seminar given at the CANMET/EEC Meeting in Ottawa, May 10, 1988.

The use of applied mineralogy in zinc processing. Invited Seminar presented at Queen's University, June 29, 1988.

Behaviour of silver during the electrorefining of copper. Thirteenth International Symposium on Mining, Extraction and Processing of Precious Metals, Montreal, June 14-16, 1989.

The hydrothermal conversion of jarosite-type compounds to hematite. GDMB-TMS Symposium on Productivity and Technology in the Metallurgical Industries, Cologne, Germany, September 17-21, 1989.

DIVISIONAL REPORTS:

Since 1984, a total of 46 Division Reports have been prepared on a variety of subjects. Illustrative examples are listed below.

Dutrizac, J.E. and Chen, T.T. (1984): Examination of Las Cuevas, Mexico, acid grade-fluospas concentrate. MRP/MSL 84-1 (CR).

Dutrizac, J.E. and Chen, T.T. (1984): Mineralogical examination of three leach residues from the pressure leaching of zinc middlings. MSL-INT 84-26 (Confidential).

Dutrizac, J.E. and Chen, T.T. (1984): A mineralogical examination of silver flotation concentrates made from zinc leach residues. MRP/MSL 84-124 (TR).

MacKinnon, D.J., Dutrizac, J.E. and Hardy, D.J. (1985): Cementation of silver and copper on lead dust and chemical up-grading of the cement product. MRP/MSL 85-46 (TR).

Dutrizac, J.E. (1985): English translations of a series of twelve Japanese papers on anode passivation in copper refining. MRP/MSL 85-56 (TR).

Dutrizac, J.E. (1985): Jarosite formation in the uranium processing circuit of Denison Mines Limited, Elliot Lake, Ontario. MRP/MSL 85-57 (TR).

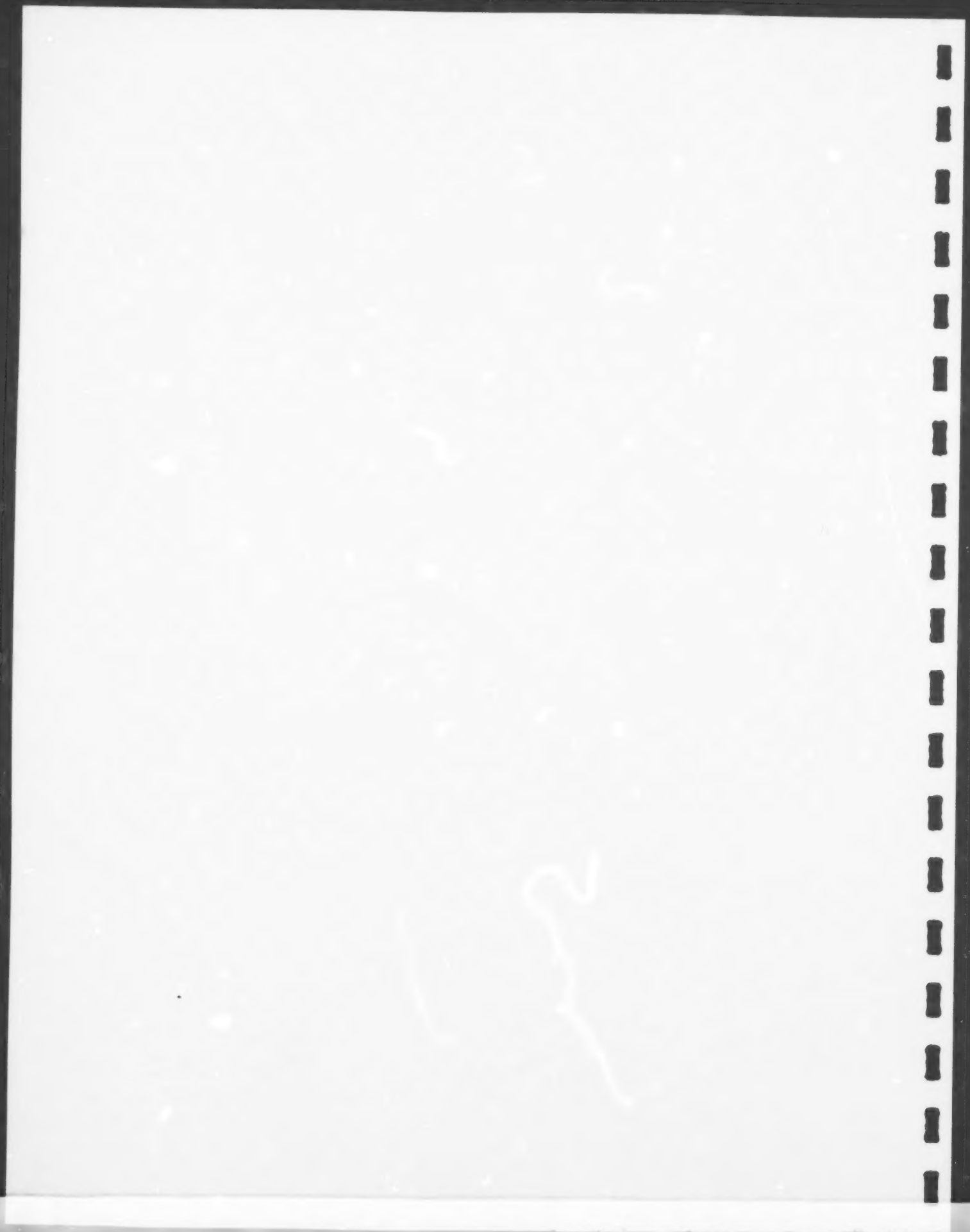
Dutrizac, J.E. and Chen, T.T. (1985): A mineralogical study of the phases formed during the $\text{CuSO}_4\text{-H}_2\text{SO}_4\text{-O}_2$ autoclave leaching of precious metals-bearing nickel-copper matte. MRP/MSL 85-21 (CR).

Dutrizac, J.E. (1987): Participation in a meeting of an international group of zinc producers and visits to five European zinc refineries, September 12-24, 1987. MSL-INT 87-40.

Chen, T.T. and Dutrizac, J.E. (1987): Mineralogical characterization of two alunite and two natrojarosite samples. MSL 87-75 (TR).

Dutrizac, J.E. (1989): The CANMET ferric chloride leach process-sulphate control and lead chloride electrolysis. MSL-INT 89-2.

Dutrizac, J.E. and Weatherell, C.J. (1989): The relative washing of zinc and cadmium from jarosite precipitates. MSL 89-96 (TR).



CURRICULUM VITAE

NAME: D.J. MacKinnon

DEGREES: Ph.D. - 1969, University of Ottawa
M.Sc. - 1964, St. Francis Xavier University
B.Sc. - 1963, St. Francis Xavier University

EXPERTISE:

Conducts research and experimental developmental (R&D) work in solution purification and metal recovery by cementation reactions, the application of electrochemical techniques for the recovery of metals from sulphide minerals and the recovery of metals from aqueous and fused salt electrolytes by electrowinning. Recent studies have included research and developmental work on zinc electrowinning from aqueous chloride electrolyte (patent awarded) as well as fundamental studies on zinc electrowinning from sulphate electrolyte (in co-operation with Cominco Ltd., and more recently with Falconbridge Ltd., Kidd Creek Division), the electrochemical leaching of sulphide minerals and on the cementation of copper and silver from chloride solutions.

CAREER:

1982 - present	Research Scientist 3, CANMET
1975-1982	Research Scientist 2, CANMET
1969-1975	Research Scientist 1, CANMET

PROFESSIONAL AFFILIATIONS:

Editorial Board	Hydrometallurgy
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CURRENT RESEARCH & OTHER ACTIVITIES:

- Zinc Processing: A joint CANMET/Kidd Creek cost recovery project to determine the optimum combination of addition agents to yield high quality zinc deposits at maximum current efficiency is continuing (30% of time).
- Zinc Processing: Fundamental studies to determine the role of organics and "inert" inorganic species; e.g., Mn, MgSO₄, etc. in zinc electrowinning are underway (20% of time).
- Impurities in Copper Refining: Electrochemical techniques are being used to investigate the role of impurities in anode passivation during copper electrorefining (20% of time).

- (d) **Electrochemical Cell Design and Development:** Development of electrochemical cells for recovering metals from dilute process streams. Possible joint project with INCO and ECOPLASTICS to develop HSA cell technology to recover Cu and As from Thompson nickel refining electrolyte (10% of time).
- (e) **Administrative:** Including contracts, technology transfer and preparation time (15% of time).
- (f) **Committee Duties:** Including refereeing and reviewing manuscripts and grant proposals (5% of time).

SCIENTIFIC CONTRIBUTIONS:

1. Zinc Chloride Electrolysis

Developed an efficient electrowinning procedure for producing smooth, compact, dendrite-free zinc deposits from aqueous chloride electrolyte that was a major factor in establishing the chloride route as a viable option for recovering zinc from complex sulphide ores. (Patent awarded)

2. Zinc Electrowinning

Fundamental studies on the role of organics and metallic impurities in zinc electrowinning have resulted in a better understanding of the process and have been of considerable help to the zinc industry in the development of an automation technique for controlling zinc cell house operation.

3. Addition Agents for Zinc Electrowinning

Currently, a cost-shared cooperative research project with Kidd Creek is aimed at defining the best combination and concentration of addition agents to consistently produce quality zinc deposits at maximum current efficiency in the Kidd Creek zinc operation.

4. Chloride Cementation

Recent studies on metal recovery from leach solutions using cementation techniques have resulted in the development of an iron cementation stage for recovering copper and silver in CANMET's ferric chloride leach process.

5. Impurities in Copper Refining

Fundamental electrochemical studies coupled with SEM/EDX techniques have provided significant data on the role of impurities in anode passivation during copper electrorefining.

REFEREED JOURNAL ARTICLES:

- MacKinnon, D.J., Brannen, J.M. and McMillan, R.S. (1985): Factors Affecting the Structure of Copper Deposits Electrowon from Aqueous Chloride Electrolyte. *J. Appl. Electrochem* 15, 649-658.
- MacKinnon, D.J. (1985): The Effect of Copper on Zinc Electrowinning from Industrial Acid Sulphate Electrolyte. *J. Appl. Electrochem* 15, 953-960.
- MacKinnon, D.J., Morrison, R.M. and Brannen, J.M. (1986): The Effects of Nickel and Cobalt and their Interaction with Antimony on Zinc Electrowinning from Industrial Acid Electrolyte. *J. Appl. Electrochem* 16, 53-61.
- MacKinnon, D.J. and Brannen, J.M. (1986): Aluminum Cathode Effects in Zinc Electrowinning from Industrial Acid Sulphate Electrolyte. *J. Appl. Electrochem* 16, 127-133.
- MacKinnon, D.J., Brannen, J.M. and Fenn, P.L. (1986): The Effects of As(III) and As(V) on Zinc Electrowinning from Industrial Acid Sulphate Electrolyte. *J. Appl. Electrochem* 16, 899-906.
- Morrison, R.M., MacKinnon, D.J. and Brannen, J.M. (1987): Silver Cementation from Chloride Solution Using Rotating Disks of Copper and Lead. *Hydrometallurgy* 18, 207-223.
- MacKinnon, D.J., Brannen, J.M. and Fenn, P.L. (1987): Characterization of Impurity Effects in Zinc Electrowinning from Industrial Acid Sulphate Electrolyte. *J. Appl. Electrochem* 17, 1129-1143.
- MacKinnon, D.J., Dutrizac, J.E., Brannen, J.M. and Hardy, D.J. (1988): Behaviour of thiourea and Flotation Reagents in Zinc Electrowinning Circuits. *Metallurgical Transactions* 19B, 187-199.
- MacKinnon, D.J., Brannen, J.M. and Morrison, R.M. (1988): The Effect of Thiourea on Zinc Electrowinning from Industrial Acid Sulphate Electrolyte. *J. Appl. Electrochem* 18, 252-256.

MacKinnon, D.J. (1989): The Early History of Nickel Electrorefining in Canada. CIM Bulletin 82(927), 65-68.

ORAL PRESENTATIONS - CANADA

MacKinnon, D.J.: Effects of Ag, Se and O₂ in the Passivation of Copper Anodes and the Electrowinning of Copper Arsenide. Copper Refining Group Meeting, CANMET, October 26, 1987.

MacKinnon, D.J.: Overview of CANMET's Zinc Electrowinning Program. Canadian Zinc Processors Meeting, Canadian Electrolyte Zinc, Valleyfield, Quebec, October 1987.

MacKinnon, D.J.: Reagent Addition Effects in Zinc Electrowinning from Kidd Creek Electrolyte. Canadian Zinc Processors Meeting, Timmins, Ontario, April 1989.

DIVISIONAL REPORTS:

MacKinnon, D.J., Dutrizac, J.E. and Hardy, D.J. (1985): Cementation of Silver and Copper on Lead Dust and Chemical Upgrading of the Cement Product. Mineral Sciences Laboratories Division Report 85-46 (TR).

MacKinnon, D.J. and Brannen, J.M. (1985): Zinc Dust Cementation of Bismuth, Cadmium, Cobalt, Copper, Lead and Nickel from Chloride Solutions. Mineral Sciences Laboratories Division Report 85-136 (TR).

MacKinnon, D.J. and Fenn, P.L. (1985): The Effects of Less Commonly Encountered Impurities on Zinc Electrowinning from Industrial Acid Sulphate Electrolyte. Minerals Sciences Laboratories Division Report 85-144 (TR).

MacKinnon, D.J. and Brannen, J.M. (1986): Lead Electrowinning from Aqueous Chloride Electrolyte. Mineral Sciences Laboratories Division Report 86-42 (TR).

MacKinnon, D.J. and Brannen, J.M. (1986): Cementation of Copper and Silver on Granular Iron from Simulated Iron Chloride Leach Solutions. Mineral Sciences Laboratories Division Report 86-107 (TR).

Morrison, R.M. and MacKinnon, D.J. (1987): Electrowinning of Particulate Copper from Cuprous Chloride Media. Mineral Sciences Laboratories Internal Report 87-7.

- Morrison, R.M. and MacKinnon, D.J. (1987): Literature Survey on the Electrodeposition of Copper-Arsenic Alloys. Mineral Sciences Laboratories Literature Survey 87-25 (LS).
- MacKinnon, D.J. and Morrison, R.M. (1987): The Electrowinning of Copper Arsenide. Mineral Sciences Laboratories Division Report 87-157 (TR).
- MacKinnon, D.J. and Morrison, R.M. (1989): The CANMET-KIDD CREEK LTD. Joint Project on Zinc Electrowinning - Final Report. Mineral Sciences Laboratories Division Report 89-6 (CR).
- MacKinnon, D.J. and Morrison, R.M. (1989): The CANMET-KIDD CREEK LTD. Joint Project on Zinc Electrowinning - Executive Summary. Mineral Sciences Laboratories Division Report 89-8 (CR).
- MacKinnon, D.J. (1989): The CANMET Ferric Chloride Leach Process - Zinc Chloride Electrolysis. Mineral Sciences Laboratories Internal Report 89-9.
- MacKinnon, D.J., Morrison, R.M., Mouland, J.E. and Warren, P.E. (1989): The Effects of Antimony and Glue on Zinc Electrowinning from Kidd Creek Electrolyte. Mineral Sciences Laboratories Division Report 89-73 (J) Draft.

PARTICIPATION IN NATIONAL/INTERNATIONAL MEETINGS (OTHER THAN ORAL PRESENTATIONS)

- 1986: Publicity Chairman - International Symposium on Iron Control in Hydrometallurgy, Toronto, Ontario.

CURRICULUM VITAE

NAME: Ronald Molnar

DEGREES: Ph.D. (Metall.) 1980, University of London, Imperial College, Royal School of Mines
 DIC 1980, University of London, Imperial College
 B.Eng. (Metall. Eng.) 1972, McGill University)

EXPERTISE:

Metallurgical engineering with specialization in solvent extraction of metals from aqueous solutions including evaluation of systems, engineering of circuits from bench-scale data, design, operation and construction of pilot circuits using specialized equipment. Also expert in kinetics studies on solvent extraction systems. Experienced in direct reduction technologies for iron production from ore and by-product oxide sources and in secondary steelmaking and wire rod mill operation. Experienced in steel foundry practices. Also have experience in different aspects of chemistry of hydrometallurgical systems, unit operations in hydrometallurgy and in pyrometallurgy.

CAREER:

1989 - present	Section Head, Solution Purification, CANMET
1983 - 1989	Research Scientist 2, CANMET
1982 - 1983	Research Scientist 1, CANMET
1980 - 1982	Research Metallurgist, IVACO Ltd., Eastern Steelcasting Division
1976 - 1980	Ph.D. candidate, University of London, Imperial College, Royal School of Mines
1975 - 1976	Masters candidate, IC, RSM
1972 - 1975	Research Engineer, Steel Castings Institute of Canada

PROFESSIONAL AFFILIATIONS:

Canadian Institute of Mining and Metallurgy (CIM)
The Metallurgical Society, American Institute of
Mining, Metallurgical and Petroleum Engineers (TMS-
AIME)

CURRENT RESEARCH & OTHER ACTIVITIES:

- (a) Cost recovery projects - waiting for response on various proposals and for samples to begin work on one project for \$70,000. (25%)
- (b) Section administrative responsibilities including budgeting, research planning, resource allocation, equipment and facilities purchasing, upkeep and maintenance, supervision of visiting scholars. (35%)
- (c) Branch/Division administrative responsibilities including contracts, technology transfer, preparation of proposals, program reviews, client and public interactions, transportation of dangerous goods responsibilities. (25%)
- (d) Copper processing: A joint CANMET/Industry project to examine various aspects of copper processing - removal of nickel from copper electrolytes. (10%)
- (e) Assistant editor, Hydrometallurgy. (5%)

AUTHOR IN OTHER BOOKS:

G.M. Ritcey, R. Molnar, G. Pouskouleli (1985): Recovery of thorium from ores and concentrates and the production of a saleable product. Published in GMELIN Handbook Thorium volume.

ORAL PRESENTATIONS:

- Ritcey, G.M., Molnar, R., Salo, S., Weatherell, C. (1984): A low temperature process for the chlorination of base metal sulphides using sulphur monochlorides. Presented at AIME conference in Los Angeles.
- R. Molnar (1984): L'Extraction par Solvants au CANMET. Seminar presentation to Centre de recherches minérales, Quebec.
- R. Molnar, G.M. Ritcey, B.H. Lucas (1986): Recovery of pure tantalum from a pyrochlore concentrate. Presented at AIME conference in New Orleans.

R. Molnar, G.M. Ritcey, E.W. Wong (1986): Gallium extraction from Bayer Process liquor. Poster presentation at Am. Chem Soc. 191st National Meeting (1st Int. Symp. on Sep. Sci & Technol.), New York.

Ritcey, G.M., Molnar, R., Wong, E.W., Prud'homme, P.J., Riveros, P., Muir, D., Koegler, C., Gao, X. (1988): Solvent-in-pulp extraction of gold from cyanide leach slurries. Presented at International Solvent Extraction Conference, Moscow.

COST RECOVERY DIVISIONAL REPORTS:

G.M. Ritcey, B.H. Lucas, R. Molnar (1982): Pilot optimization of flowsheet for treatment of pyrochlore concentrate for the recovery of niobium and tantalum. CANMET Divisional Report MRP/MSL 82-3(CR).

R. Molnar, G.M. Ritcey, E.W. Wong (1984): Extraction of gallium from spent Bayer Process liquors. CANMET Divisional Report MRP/MSL 84-6(CR).

G.M. Ritcey, R. Molnar, E.W. Wong (1986): Treatment of uranium process raffinate at Key Lake Uranium Mines Ltd., for the recovery of nickel. CANMET Divisional Report MSL 86-15(CR).

E.W. Wong, R. Molnar (1986): Progress report on recovery of rare earths by solvent extraction. CANMET Divisional Report MSL 86-18(CR).

R. Molnar (1987): Pilot plant testing of nickel precipitation from Key Lake Mining Corporation uranium raffinate. CANMET Divisional Report MSL 87-7(CR).

R. Molnar, P.J. Prud'homme, G.M. Ritcey, E.W. Wong (1987): Solvent extraction of platinum from chloride liquor. CANMET Divisional Report MSL 87-10(CR).

R. Molnar, G.P. Demopoulos, K. Quon (1989): Recovery of iron from zinc process solutions. CANMET Divisional Report MSL 89-3(CR).

DIVISIONAL REPORTS:

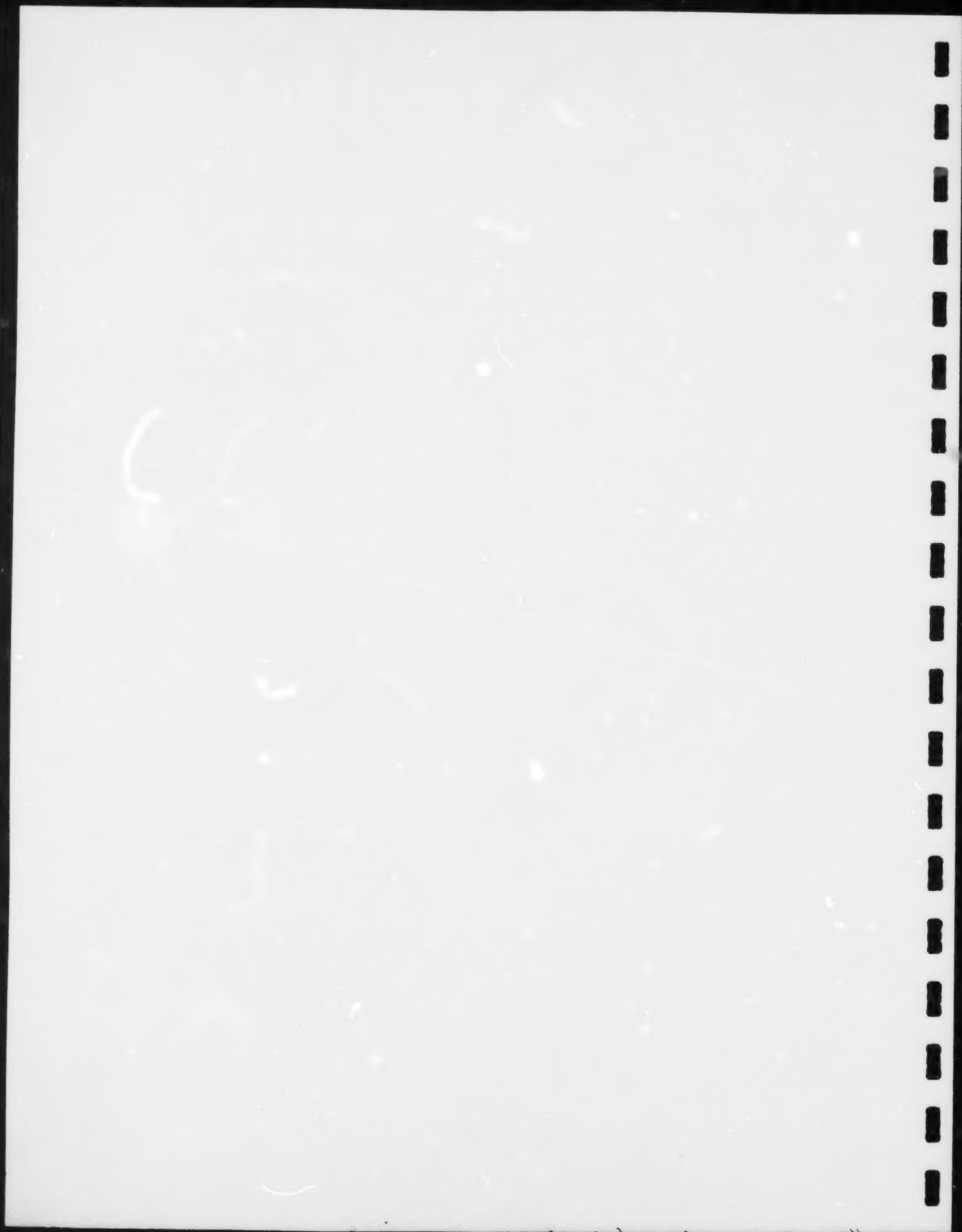
R. Molnar (1985): Royal Canadian Mint pilot plant for solvent extraction of platinum and palladium. CANMET Divisional Report MSL 86-11(TR).

- R. Molnar (1985): Royal Canadian Mint pilot plant for solvent extraction of copper. CANMET Divisional Report MSL 86-12(TR)
- X. Gao, R. Molnar (1987): Solvent extraction of gold from leach slurry; Final report of training at CANMET. CANMET Divisional Report MSL 87-140.

PATENTS (AND APPLICATIONS):

- F.T. Awadalla, R. Molnar, G.M. Ritcey (1989: Recovery of Platinum Group Metals from Acidic Solutions by Reduction Precipitation with Sodium Borohydride. Canadian patent application filed.

BIOTECHNOLOGY



CURRICULUM VITAE

NAME: William Douglas Gould

DEGREES: B.Sc. - Chemistry, University of Manitoba, 1965
M.Sc. - Soil Microbiology, University of Alberta, 1970
Ph.D. - Soil Microbiology, University of Alberta, 1976

EXPERTISE:

Soil microbiology, organic and inorganic chemistry,
microbial ecology.

<u>CAREER:</u>	1986-present	Biohydrometallurgist, C A N M E T , Department of Energy, Mines and Resources, Ottawa
	1983-present	Adjunct Assistant Professor College Environmental Science and Forestry State University of New York, Syracuse
	1982-1985	Research Microbiologist, Allied Corporation, Syracuse Research Laboratory
	1979-1982	Environmental Microbiologist, Agriculture Canada, Lethbridge Research Station
	1976-1979	Postdoctoral Fellow, Colorado State University
	1966-1967	Chemist, Kalium Chemicals Ltd., Belle Plaine, Saskatchewan

PROFESSIONAL AFFILIATIONS:

American Society for Microbiology
Canadian Society of Microbiologists
International Society of Soil Science
Society for Industrial Microbiology
Society of Sigma Xi
Soil Science Society of America
The Canadian Institute of Mining and
Metallurgy

AWARDS:

1. Energy Mines and Resources Merit Award, April 1989

CURRENT RESEARCH & OTHER ACTIVITIES:

- (a) Development of biological processes for environmental protection from industrial effluents. (70% of time)
- (b) BIOMINET Networking activities. (10% of time)
- (c) Bacterial leaching of ores. (10% of time)
- (d) Cost recovery, proposal development and discussions with industry. (5% of time)
- (e) Review of grant proposals and manuscripts. (5% of time)

SIGNIFICANT CONTRIBUTIONS:

1. Supervised an M.Sc. student (Carleton University) in the development of a process to degrade an organic pollutant in a mill effluent. A patent has been filed on the process and it will be scaled up for a pilot plant test at the mine site in 1990.
2. Assisted in the development of a process for the bacterial reduction and removal of selenium from weak acid smelter effluents. A patent has been filed on this process.
3. Have made several fundamental contributions to the knowledge of bacterial leaching of metal sulphides. Completed a study on the preferential and sequential leaching of a complex sulphide ore and identified the order in which the various sulphide minerals are attacked.

Also showed that a mixed culture of T. thiooxidans and T. ferrooxidans was more effective than single pure cultures or chemical leaching for metal solubilization.

Completed a stable isotope study to determine the oxygen source for sulphate production during bacterial leaching of sulphide ores.

4. Developed a process for the degradation of deicing fluids in airport runoff. A patent application will be filed shortly.

5. Assisted in the preparation and presentation of a course on "Basic Microbiology for the Mineral Industry". This course has been presented annually for the last three years.

REFEREED JOURNAL ARTICLES:

- Gould, W.D., Hagedorn, C., Bardinelli, T.R. and Zablotowicz, R.M. 1985. New selective media for enumeration and recovery of fluorescent pseudomonads from various habitats. Appl. Environ. Microbiol. 49:28-32.
- McLean, R.J.C., Cheng, K.-J., Gould, W.D. and Costerton, J.W. 1985. Cytochemical localization of urease in a rumen *Staphylococcus* sp. by electron microscopy. Appl. Environ. Microbiol. 49:253-255.
- Bole, J.B. and Gould, W.D. 1985. Irrigation of forages with rendering plant wastewater: Forage yield and nitrogen dynamics. J. Environ. Qual. 14:119-126.
- Ingham, R.E., Anderson, R.V., Gould, W.D. and Coleman, D.C. 1985. Vertical distribution of nematodes in a shortgrass prairie. Pedobiologia 28:155-160.
- Bole, J.B., Gould, W.D. and Carson, J.A. 1985. Yields, nutrient and metal content of forages irrigated with wastewater, and the fate of added ¹⁵N labelled fertilizer nitrogen. Agron. J. 77:715-719.
- Bole, J.B. and Gould W.D. 1986. Overwinter losses of nitrogen-15 labelled urea fertilizer. Can. J. Soil Sci. 66:513-520.
- McLean, R.J.C., Cheng, K.-J., Gould, W.D., Nickel, J.C. and Costerton, J.W. 1986. Histochemical and biochemical urease localization in the periplasm and outer membrane of two *Proteus mirabilis* strains. Can. J. Microbiol. 32:772-778.
- Gould, W.D., Hagedorn, C. and McCready, R.G.L. 1986. Urea transformations and fertilizer efficiency in soil. Adv. Agron. 40:209-238.
- Nakas, J.P., Gould, W.D. and Klein, D.A. 1987. Origin and expression of phosphatase activity in a semi-arid grassland soil. Soil Biol. Biochem. 19:13-18.
- Hagedorn, C., Gould, W.D., Bardinelli, T.R. and Gustavson, D.R. 1987. A selective medium for enumeration and recovery of *Pseudomonas cepacia* biotypes from soil. Appl. Environ. Microbiol. 53:2265-2268.

Hagedorn, C., Gould, W.D. and Bardinelli, T.R. 1989. Rhizobacteria of cotton and their repression of seedling disease pathogens. Appl. Environ. Microbiol. (In press).

PATENTS:

Brassinga et al, Biodegradation of oxalate ions in aqueous solutions. File # 574,176, Patent Pending.

McCready et al, Biorecovery of Selenium. File # 580,256. Patent Pending

McCready et al, Biodegradation of urea and ethylene glycol using a rotating biological contactor and a selected organism. Patent to be filed by October 1, 1989.

BOOKS:

Gould, W.D., Hagedorn, C. and McCready, R.G.L. 1986. Urea transformation and fertilizer efficiency in soil. Adv. Agronomy, 40:209-238.

McCready, R.G.L. and Gould, W.D. 1990. Bioleaching of Uranium. in Microbial Mineral Recovery, Edited by H.L. Erlich, J.A. Brierley and C.L. Brierley, McGraw-Hill Publ., New York, N.Y. (In press).

Gould, W.D. 1989. Biological control of plant root diseases using bacteria. in "Biotechnology of Plant-Microbe Interactions" J.P. Nakas and C. Hagedorn (eds) McMillan and Co. New York. (In press).

ORAL PRESENTATIONS:

Hagedorn, C., Gould, W.D., Bardinelli, T.R. and Gustavson, D.R. 1985. A selective medium for enumeration and recovery of *Pseudomonas cepacia* biotypes from soil. p 155. Abs. 85th. Ann. Meeting, Am. Soc. Microbiol.

Hagedorn, C., Gould, W.D. and Bardinelli, T.R. 1985. Characterization of the bacterial populations associated with the cotton rhizoplane. pp.31-32. In Proceedings of the Beltwide Cotton Production Research Conferences. January 6-11, 1985. National Cotton Council of America, Memphis, Tenn.

- Gould, W.D., Hagedorn, C. and Bardinelli, T.R. 1986. A *Pseudomonas putida* isolate displaying a wide range of physiological activities. p.256. Abstracts of the 86th Annual Meeting, American Society for Microbiology.
- McLean, R.J.C., Cheng, K.-J., Gould, W.D., Nickel, J.C. and Costerton, J.W. 1986. Cytochemical and biochemical urease localization in two *Proteus mirabilis* strains. p.97. Canadian Society of Microbiologists 36th Annual Conference, 1986.
- Gould, W.D., Hagedorn, C., Bardinelli, T.R. and Zablotowicz, R.M. 1986. Improved selective media for enumeration and recovery of fluorescent pseudomonads from soil. Biol. Agric. Hort. 3:367-369.
- Gould, W.D., Beaudette, L. and McCready, R.G.L. 1987. Destruction of cyanide from gold mill effluents using enzymes. p.25-37, In Proceedings of the Third Annual General Meeting of BIOMINET, R.G.L. McCready (ed.), August 20-21, 1986, Toronto, Canada, Publication SP 86-9.
- Gould, W.D., Krouse, H.R., McCready, R.G.L. and Rajan, S. 1988. Stable isotope composition of sulphate produced during bacterial oxidation of various metal sulphides. p.54. Canadian Society of Microbiologists 38th Annual Conference, 1988.
- Sanmugasunderam, V., Gould, W.D., McCready, R.G.L., Rajan, S., Beaulne, M. and Mainwaring, P. 1988. Bacterial and chemical leaching of complex sulphide ores. p.103-116, In Proceedings of the Fourth Annual General Meeting of BIOMINET, R.G.L. McCready (ed.) November 5, 1987, Sudbury, Canada. CANMET Special Publication SP 87-10.
- Gould, W.D., McCready, R.G.L., Rajan, S. and Krouse, H.R. 1989. Stable isotope composition of sulphate produced during the bacterial oxidation of various metal sulphides. in Proc. Intl. Symp. Biohydrometallurgy, Edited by P. Wichlacz, R.G.L. McCready, J. Salley and J. Hollington, (In press).

CANMET PUBLICATIONS:

McCready, R.G.L., Sanmugasunderam, V. and Gould, W.D. 1986. Workshop on Basic Microbiology for the Mineral Industry, CANMET SP 86-7.

DIVISIONAL REPORTS:

Over the past three years I have prepared 8 Divisional Reports, three examples are listed below:

Sanmugasunderam, V., Gould, W.D., McCready, R.G.L., Rajan, S., Beaulne, M. and Mainwaring, P. 1987. Bacterial and chemical leaching of complex sulphide ores, MSL 87-145 (OP+J).

Gould, W.D., McCready, R.G.L., Rajan, S. and Krouse, H.R. 1988. Stable isotope composition of sulphate production during bacterial oxidation of various metal sulphides, MSL 88-73 (OP).

Gould, W.D., McCready, R.G.L., Salley, J., Rajan, S., Chalykoff, C. and Beaudette, L. 1988. Microbial treatment of industrial effluents, MSL 88-131 (OP+J).

CURRICULUM VITAE

NAME: R.G.L. McCready

DEGREES: B.Sc. Pharmacy, University of Alberta, 1961.
M.Sc. Microbiology, University of Alberta, 1963.
Ph.D. Microbial Metabolism and Physiology,
The University of Calgary, 1973.

EXPERTISE:

Microbial metabolism and physiology, industrial microbiology, microbial ecology with an above average understanding of both organic and inorganic chemistry.

<u>CAREER:</u>	1985-present	Head, Biotechnology Section, CANMET, EMR, Ottawa, Ontario
	1982-1985	Associate Professor, Dalhousie University, Halifax, N.S.
	1978-1982	Biophysical Chemist, Agriculture Canada, Lethbridge, Alberta
	1975-1978	Staff Microbiologist, CANMET, EMR
	1973-1975	Research Associate, UNISUL, The University of Calgary.

PROFESSIONAL AFFILIATIONS:

The Canadian Society for Microbiology
The American Society for Microbiology
The Society for Industrial Microbiology
The Alberta Pharmaceutical Association
The Canadian Pharmaceutical Association

AWARDS:

Energy, Mines and Resources Merit Award, April, 1989

CURRENT RESEARCH & OTHER ACTIVITIES:

- (a) Research coordination and discussions with staff to resolve technical or analytical problems. (40% of time)
- (b) BIOMINET Networking Activities. (15% of time)
- (c) Interdepartmental Committees. (10% of time)
- (d) Monitoring of external contracts. (15% of time)
- (e) Administration of the Section. (10% of time)
- (f) Refereeing and reviewing manuscripts and grant proposals. (5% of time)
- (g) Cost Recovery: Preparing proposals, co-ordinating work on the various projects. (5% of time)

SIGNIFICANT CONTRIBUTIONS:

- 1. Scientific advisor to Denison Mines for the commercialization of bacterial leaching of uranium.
- 2. Scientific advisor to HBM&S, the University of Manitoba and the Manitoba Department of Mines and Energy on bacterial leaching of copper and zinc.
- 3. Member of the Technical Committee to advise Transport Canada on remedial measures for AMD at the Halifax Airport.
- 4. Project leader for the development of the process for biorecovery of selenium.
- 5. Project leader for the development of the process to degrade an organic pollutant.
- 6. Member of the Interdepartmental Committee on Biotechnology.
- 7. Secretary for the BIOMINET Network.

REFEREED JOURNAL ARTICLES:

McCready, R.G.L. and Zentilli, M. 1985. A feasibility study on the reclamation of coal waste dumps by bacterial leaching. CIM Bull. 78:67-68.

- McCready, R.G.L. and Zentilli, M. 1985. Beneficiation of coal by bacterial leaching. *Can. Met. Quart. Rev.* 24:135-139.
- McCready, R.G.L., Wadden, D. and Marchbank, A. 1986. Nutrient requirements for the in-place leaching of uranium by *Thiobacillus ferrooxidans*. *Hydromet.* 17:61-71.
- Gibling, M.R., Zentilli, M., Mahony, H. and McCready, R.G.L. 1986. An isotopic evaluation of sulfur recycling from evaporites to coals in the Carboniferous Sydney Basin, Nova Scotia. *Current Research, Part B., Geol. Sur. of Canada, Paper 86-1B*, 73-76.
- McCready, R.G.L. and Lakshmanan, V.I. 1986. Review of bioadsorption research to recover uranium from leach solutions in Canada. pp 219-226. in *Immobilization of Ions by Bioadsorption*. Edited by H. Eccles and S. Hunt, Ellis Horwood Publ. London, England.
- McCready, R.G.L. 1987. A review of the physical, chemical and biological measures to prevent acid mine drainage: An application to the pyritic Halifax shales. *Proc. Acid Mine Drainage Seminar/Workshop*. pp. 333-355. Environment Canada, En 40-11-7/1987.
- Murray, E.W., Goudey, S.P., McCready, R.G.L. and Salley, J. 1988. Laboratory and field testing of a salt-supplemented Clay Cap as an impermeable seal over pyritic slates. pp. 52-58. *Mine Drainage and Surface Mine Reclamation. Vol. 1 Mine Water and Mine Waste. U.S.B.M. Information Circular 9183*.
- McCready, R.G.L. 1988. Progress in the bacterial leaching of metals in Canada. pp 175-195, in *Biohydrometallurgy*, Edited by P.R. Norris and D. P. Kelly, *Sci. and Technol. Letters*, Surrey, U.K.
- Cuif, J.P., Salley, J. and McCready, R.G.L. 1989. Comparison of uranium bioadsorption between *Scytalidium acidophilum* and *Rhizopus arrhizus*. *Biotech. Bioeng.* (In press)
- McCready, R.G.L. 1989. Bacterial acid generation in pyritic shales and remedial measures. pp 681-685. *Proc. Symp. on Reclamation, A Global Perspective. Vol 2*, Edited by D.G. Walker, C.B. Power and M.W. Pole. Canadian Land Reclamation Assoc.
- Tsezos, M., McCready, R.G.L. and Bell, J.P. 1989. The continuous recovery of uranium from biologically leached solutions using immobilized biomass. *Biotech. Bioeng.* 34:10-17.
- Gibling, M.R., Zentilli, M. and McCready, R.G.L. 1989. Sulphur in Pennsylvanian coals of Atlantic Canada: geologic and isotopic evidence for a bedrock evaporite source. *Intl. J. Coal Geol.* 11:81-104.

- McCready, R.G.L. 1989. Biotechnological Processes in the Canadian Mining Industry. Proc. Intl. Symp. Biotechnology for Energy. (In press)
- McCready, R.G.L. 1989. Canadian Biotechnological Developments in Fossil Fuels. Proc. Intl. Symp. Biotechnology for Energy. (In press).
- Tsezos, M., McCready, R.G.L., Salley, J. and Cuif, J.P. 1990. The use of immobilized biomass for the continuous recovery of uranium from the biological leachate of an Elliot Lake ore. Proc. Intl. Symp. Biohydrometallurgy, Edited by P. Wichlacz, R.G.L. McCready, J. Salley and J. Hollington. (In press)
- McCready, R.G.L., Salley, J. and Gould, W.D. 1990. Biorecovery of selenium from smelter effluents. Proc. Pacific Rim Congress; 1990. (In press)

REFEREED CONFERENCE PROCEEDINGS:

- Gould, W.D., Beaudette, L. and McCready, R.G.L. 1986. Destruction of cyanide from gold mill effluents using enzymes. BIOMINET Proc. pp 25-38, CANMET SP 86-9E.
- Sober, D.L., Lakshmanan, V.I. McCready, R.G.L. and Dayha, A.S. 1986. Bioadsorption of uranium by fungal stope isolates. BIOMINET Proc. pp 93-110. CANMET SP 86-9E.
- Hoppe, D.G., Witte, M.K. and McCready, R.G.L. 1986. Microbial degradation of carbonaceous material in a copper molybdenum concentrate. BIOMINET Proc. pp 147-170. CANMET SP 86-9E.
- Sanmugasunderam, V., Gould, W.D., McCready, R.G.L., Rajan, S., Beaulne, M. and Mainwaring, P. 1987. Bacterial and chemical leaching of a complex sulphide ore. BIOMINET Proc. pp 103-117, CANMET SP 87-10.
- Lakshmanan, V.I., King, D.J., Tsezos, M. and McCready, R.G.L. 1987. Optimization of fungal adsorption of uranium and cell immobilization. BIOMINET Proc. pp 119-134, CANMET SP 87-10.
- McCready, R.G.L., Salley, J. and Smith, T.G. 1987. Biorecovery of selenium. BIOMINET Proc. pp 135-146. CANMET SP 87-10.
- McCready, R.G.L., Salley, J., Hoppe, D.G. and Bartlett, D.R. 1987. Progress on emulsification and flotation as a means of upgrading a Cu/Mo concentrate. BIOMINET Proc. pp 147-155. CANMET SP 87-10.

Gould, W.D., McCready, R.G.L., Salley, J., Rajan, S., Chalykoff, C. and Beaudette, L. 1988. Microbial treatment of industrial effluents. BIOMINET Proc. pp 39-56. CANMET SP 88-23.

PATENTS:

Brassinga et al, Biodegradation of oxalate ions in aqueous solutions. File # 574,176, Patent Pending.

Lakshmanan and McCready, Bioadsorption composition, process for production thereof and process for use thereof. U.S. File # 07/387930. Patent Pending.

McCready et al, Biorecovery of Selenium. File # 580,256. Patent Pending

McCready et al, Biodegradation of urea and ethylene glycol using a rotating biological contactor and a selected organism. Patent to be filed October 14, 1989.

BOOKS:

Gould, W.D., Hagedorn, C. and McCready, R.G.L. 1986. Urea transformation and fertilizer efficiency in soil. Adv. Agronomy, 40:209-238.

McCready, R.G.L. 1990. Microbiological studies on high-sulphur Eastern Canadian Coals. in Biotechnology Applied to Fossil Fuels, Ed. D. Wise, Marcel Dekker Press, New York, N.Y. (In press).

McCready, R.G.L. and Gould, W.D. 1990. Bioleaching of Uranium. in Microbial Mineral Recovery, Edited by H.L. Erlich, J.A. Brierley and C.L. Brierley, McGraw-Hill Publ., New York, N.Y. (In press).

ORAL PRESENTATIONS:

McCready, R.G.L., Wadden, D. and Marchbank, A. 1986. Optimization of the bacterial leaching of uranium. Workshop on Biotechnology for the Mining, Metal Refining and Fossil Fuel Processing Industries. 1985. Troy, New York, N.Y.

Gibling, M.R., Zentilli, M., Mahovy, H. and McCready, R.G.L. 1986. Did sulphur in Sydney coal come from the Windser group evaporites. Atlantic Geoscience Society Ann. Meet., Amherst, N.S.

- McCready, R.G.L. and Lakshmanan, V.I. 1986. Review of biosorption research to recover uranium from leach solutions in Canada. Symp. on Immobilization of Ions by Naturally Occuring Materials as Alternatives to Ion Exchange Resins. Lancaster, England, April, 1986.
- McCready, R.G.L. 1986. Current biotechnology research in mining. 36th Ann. Meet. Can. Soc. Microbiol., Toronto, June 8-11.
- McCready, R.G.L. 1987. A review of the physical, chemical and biological measures to prevent acid mine drainage: An application to the pyritic Halifax shales. Proc. Acid Mine Drainage Seminar/Workshop. Halifax, N.S., March 23-26.
- McCready, R.G.L. 1987. Acid generation in mine tailings. Colloque Environment Minière Du Quebec, Val D'Or, Quebec, May 21.
- McCready, R.G.L. 1987. Current biotechnology research in the mining and petroleum sectors. Invited seminar, Department of Chemical Engineering, University of Saskatchewan, June 19.
- McCready, R.G.L. 1987. Progress in the bacterial leaching of metals in Canada. International Symp. on Biohydrometallurgy, Warwick, U.K., July 12-16.
- McCready, R.G.L. and Salley, J. 1987. Application of biotechnology to recover metals from dilute solutions. Ann. Conf. of Metallurgists, Winnipeg, Manitoba, August 26.
- Norcross, R.W., McCready, R.G.L. and Gould, W.D. 1987. The potential for biotechnology in the mining industry. Ann. Conf. of Metallurgists, Winnipeg, Manitoba, August 26.
- Gould, W.D., McCready, R.G.L., Rajan, S. and Krouse, H.R. 1988. Stable isotope composition of sulfate produced during bacterial oxidation of various metal sulfides. Can. Soc. of Microbiol. Ann. Meeting, Windsor, Ontario, June 20-22.
- McCready, R.G.L. and Salley, J. 1988. Biotechnological treatment of mine effluents. National Convent. of the Water Res. Assoc., Saskatoon, Sask., June 21-24.
- Gould, W.D. and McCready, R.G.L. 1988. Application of biotechnology for the Gold Mining Industry. CANMET Seminar, Timmins, Ontario, November.
- Lakshmanan, V.I. and McCready, R.G.L. 1988. Recovery of metals from dilute solutions by bioadsorption. AIME Ann. Meeting, Las Vegas, Nevada, February.

- McCready, R.G.L. 1989. Biotechnology for the Mineral Industry. Invited Seminar, U.S.B.M., Salt Lake City, Utah.
- McCready, R.G.L. 1989. Bacterial Acid Generation in Pyritic Shales and Remedial Measures. Reclamation, A Global Perspective. Calgary, Alberta, August 27-31.
- Gould, W.D., McCready, R.G.L. and Campbell, M.C. 1989. Applications of Biotechnology to the Gold Mining Industry. CIM-AGM, Quebec City, April 30-May 3, 1989.
- Tsezos, M., McCready, R.G.L., Salley, J., Cuif, J.P. 1989. The use of immobilized biomass for the continuous recovery of uranium from biological leachate of Elliot Lake ore. International Symp. of Biohydrometallurgy, Jackson Hole, Wyoming, U.S.A., August 1989.
- McCready, R.G.L. 1989. Biotechnological Processes in the Canadian Mining Industry. Intl. Symp. on Biotechnology for Energy, Faisalabad, Pakistan. Invited presentation.
- McCready, R.G.L. 1989. Canadian Biotechnological Developments in Fossil Fuels. Intl. Symp. of Biotechnology for Energy, Faisalabad, Pakistan. Invited presentation.
- McCready, R.G.L., Salley, J., Gould, W.D. Biorecovery of selenium from smelter effluents. Pacific Rim Congress, Gold Coast, Australia in 1990. Invited presentation.

CANMET PUBLICATIONS:

- McCready, R.G.L. and Sanmugasunderam, V. The Noranda Contract Report on the Pre-feasibility Study of In-place Bacterial Leaching: A Summation, CANMET Report No. 85-5E.
- McCready, R.G.L., BIOMINET Proceedings, CANMET Report SP 85-6.
- McCready, R.G.L., Sanmugasunderam, V. and Gould, W.D. Workshop on Basic Microbiology for the Mineral Industry, CANMET Report SP 86-7.
- McCready, R.G.L., BIOMINET Proceedings, CANMET Report SP 86-9E.
- McCready, R.G.L. editor, BIOMINET Proc, CANMET Report SP 88-23.

DIVISIONAL REPORTS:

Over the past five years I have written 31 divisional reports, two examples of such reports are listed.

Silver, M., Sanmugasunderam, V. and McCready, R.G.L. The role of bacteria in the formation of organic deposits on the spiral concentrators of the Mount Wright Plant, Quebec Cartier Mining Company, MRP/MSL 85-126 (TR).

McCready, R.G.L. and Salley, J. Preliminary results on the inhibition of pyrite oxidation by road salt and clay capping of Halifax pyritic shales, MSL 86-129 (TR).

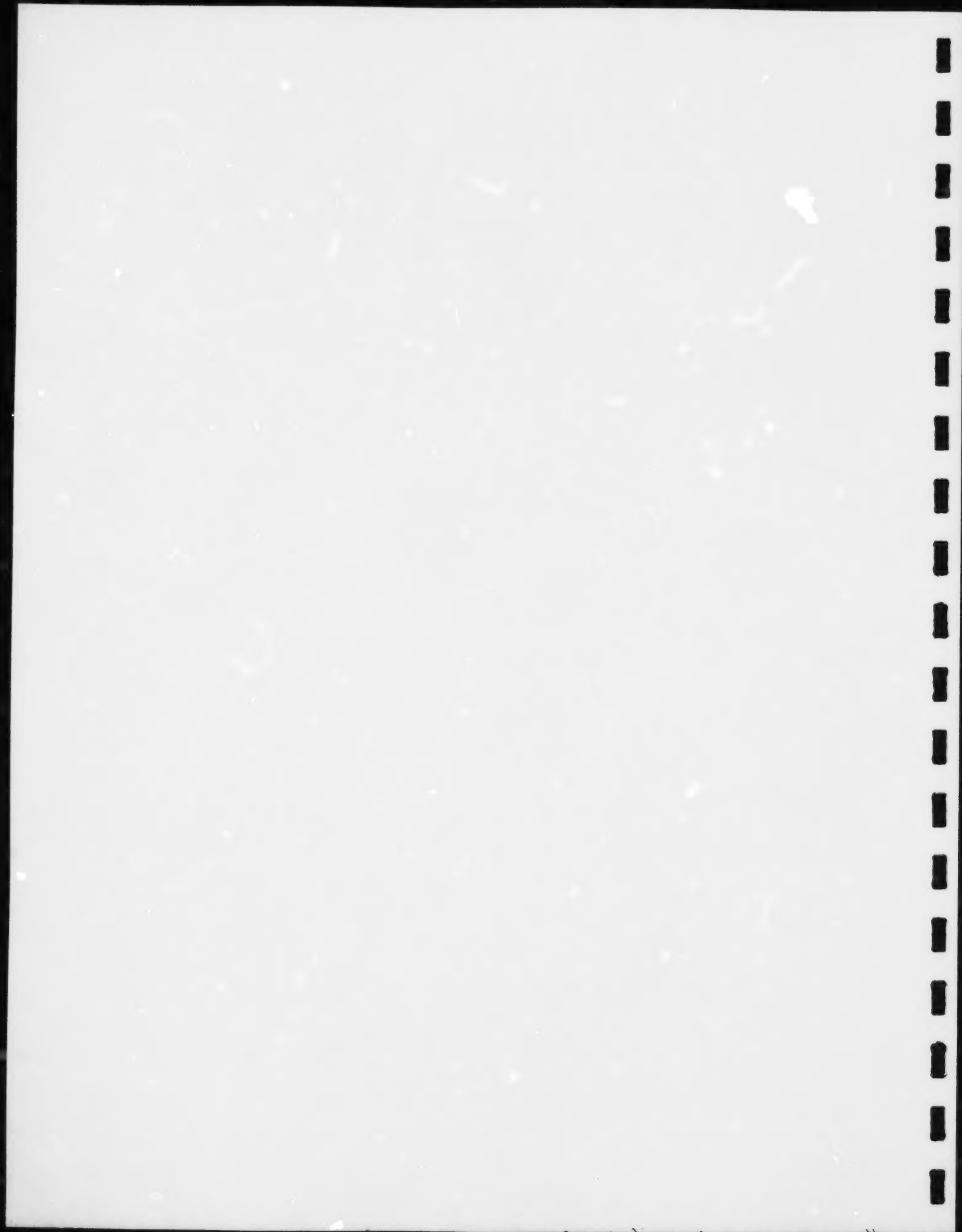
PARTICIPATION IN NATIONAL/INTERNATIONAL MEETINGS other than oral presentations):

Co-organizer and co-chairman of the 9th. International Symposium on Biohydrometallurgy, Jackson Hole, Wyoming, August 13-18, 1989.

Invited international expert to present two papers at the International Symposium on Biotechnology for Energy, Faisalabad, Pakistan, December 16-21, 1989.

Invited to present the "Basic Microbiology for the Mining Industry" course and present a current research paper at the Pacific Rim Congress; 1990, Gold Coast, Australia.

ENVIRONMENT



CURRICULUM VITAE

NAME: Michel P. Fillion

DEGREES: B.A.Sc. 1975 Chem. Eng., University of Waterloo
M.Eng. 1980 Environmental Eng., McMaster University

EXPERTISE:

Twelve and one half years of experience in the mining and mineral processing industry, with responsibilities in environmental management, planning, licensing, plant and waste decommissioning, environmental research, auditing and environmental impact preparation.

<u>CAREER:</u>	1988-present	Co-ordinator, Environmental Technology, CANMET, Ottawa
	1987-1988	Head, Environment and Waste Management, Eldorado Resources
	1981-1987	Waste Management Specialist, Eldorado Resources
	1980-1981	Branch Manager, James F. MacLaren Ltd., Saskatoon
	1977-1980	Project Engineer, James F. MacLaren Ltd., Toronto

PROFESSIONAL AFFILIATIONS:

Association of Professional Engineers of Saskatchewan
Engineering Institute of Canada
Canadian Nuclear Society

CURRENT RESEARCH & OTHER ACTIVITIES:

- (a) MEND program: Continue to coordinate activities of the program and provide the secretariat. Participate as technical reviewer of projects and participant on the 6 technical committees. Continue the search for new and better research ideas. Promote the program with industry, the five provinces and the federal government. (80% of time)
- (b) EMR Environmental Policy: CANMET representative at EMR environmental policy meetings. (5% of time)

- (c) CANMET Environmental Research: Promote coordinated research at CANMET. Major thrust currently directed at assembling an integrated team to develop new technologies for the concept of zero effluent mills. (10% of time)
- (d) Psychromechanical Process for Treatment of Mine and Mill Effluents: Continue to promote research into the treatment of mine and mill effluents by freeze crystallization. (5% of time)

SIGNIFICANT CONTRIBUTIONS:

1. Mine Environment Neutral Drainage (MEND) Program, 1988-89

Planned, coordinated and organized the research activities of the Mine Environment Neutral Drainage Program. Obtained the cooperation of industry and five provinces to participate in the program. During the first year, 22 research projects were initiated for a financial commitment of \$ 3.1 million. These commitments are divided as follows: federal government 44%, industry 39%, provinces 17%. By the end of the program, the projected \$ 12.5 million in expenditures will have been divided equally amongst the three parties.

2. Collins Bay A-Zone, D-zone and Eagle Point Environmental Impact Statement, 1986-88

As part of an Eldorado team, designed and implemented baseline studies and prepared an environmental impact statement for 3 new uranium ore bodies in northern Saskatchewan. Successfully defended the impact statement during the formal Saskatchewan and Atomic Energy Control Board review process. The mining approvals assure that the mine will continue to operate for 20 years.

3. Decommissioning of the Beaverlodge Mine/Mill Complex and Reclamation of the Site, 1985

Completed a 3 1/2 year effort to decommission and reclaim the Beaverlodge uranium mine in northern Saskatchewan. The project involved the development of decommissioning and reclamation plans, an environmental and pathways analysis of the decommissioned site, obtaining approvals from the responsible provincial and federal regulatory agencies, and carrying-out the plan to the satisfaction of all concerned parties. Close-out costs totalled \$ 50 million, of which \$ 10 million were direct environmental costs. This mine site, to our knowledge, was the first in the world to be closed in the modern age of strict regulatory review and environmental criteria.

PUBLIC DOCUMENTS:

Roberts, J.R & Filion, M.P.(1986): Cost-Benefit Analysis of Close-out Options for a Uranium Mill Tailings Area, Proceedings of the 2nd International Conference on Radioactive Waste Management, Winnipeg, Manitoba, September 7 - 11, 1986.

Co-author (October, 1986): Departure with Dignity, Decommissioning of the Beaverlodge Mine/Mill Operations and Reclamation of the Site, Eldorado Resources Limited.

Co-author (May 1986): Project Review, Environmental Impact Statement Collins Bay A-Zone, D-Zone and Eagle Point Development, Eldorado Resources Limited.

Co-author (June 1987): Response to Technical Review Comments, Environmental Impact Statement Collins Bay A-Zone, D-Zone and Eagle Point Development, Eldorado Resources Limited.

Co-author (June 1987): Eagle Point Project Description and Preliminary Safety Report, Environmental Impact Statement Collins Bay A-Zone, D-Zone and Eagle Point Development, Eldorado Resources Limited.

DIVISIONAL REPORTS:

Filion M. P. (September 1988): The Mine Environment Neutral Drainage (MEND) Program and Progress to Date, Mineral Sciences Laboratories Division Report MSL 88-115.

Filion M.P. and Ferguson, K.(August 1989): Acid Mine Drainage Research in Canada, Proceedings, 28th Annual Conference of Metallurgists, Canadian Institute of Mining and Metallurgy, Halifax, Nova Scotia.

Briefing notes for the Assistant Deputy Minister, Deputy Minister and Minister.

ORAL PRESENTATIONS - CANADA:

Acid Mine Drainage Research in Canada, Annual Meeting of the Geological Association of Canada and the Mineralogical Association of Canada, May 15-17, 1989.

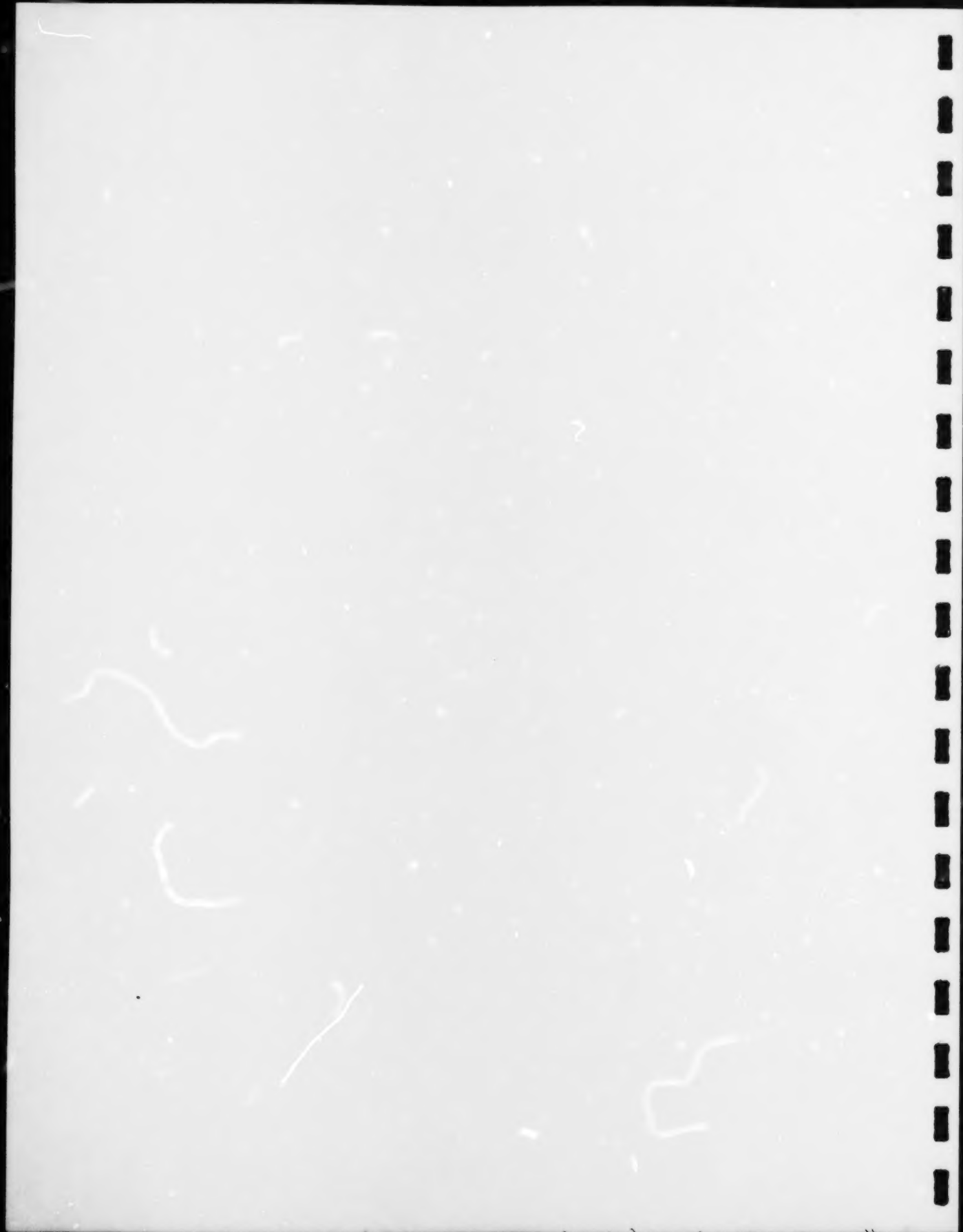
Acid Mine Drainage Research in Canada, 28th Annual Conference of Metallurgists, Canadian Institute of Mining and Metallurgy, Halifax, Nova Scotia.

PARTICIPATON IN NATIONAL/INTERNATIONAL MEETINGS (other than oral presentations):

Member of the conference organizing committee and session chairman,
2nd International Conference on Radioactive Waste Management,
Winnipeg, Manitoba, September 7 - 11, 1986.

Session chairman, 28th Annual Conference of Metallurgists, Canadian
Institute of Mining and Metallurgy, Halifax, Nova Scotia,
August 1989.

CONCRETE TECHNOLOGY



CURRICULUM VITAE

NAME: V. Mohan Malhotra

DEGREES: D.D.L. (Honorary) 1984, University of Dundee, Scotland
B.E. (Civil) 1957, University of Western Australia
B.Sc. 1951, University of Delhi

EXPERTISE:

Specialist in concrete technology with emphasis on:
Long-term durability of concrete, NDT, utilization of
supplementary cementing materials, high strength
lightweight and normal weight concretes, specialized
concretes for offshore structures, use of fly ash, blast-
furnace slag, silica fume and natural pozzolans, alkali
aggregate reactions in concrete and supplementary
cementing materials for mine backfill.

CAREER:

1974 - present	Research Scientist 4, CANMET, Ottawa
1962 - 1974	progressively, Scientific Officer, Research Scientist 2, Research Scientist 3, CANMET, Ottawa
1960 - 1962	Materials Engineer, Geocon Ltd., Montreal
1957 - 1960	Materials Engineer, Snowy Mountains Authority, Sydney, Australia

PROFESSIONAL AFFILIATIONS:

Honorary Member	American Concrete Institute (U.S.A.)
Honorary Member	Concrete Society (U.K.)
Charter Fellow	American Concrete Institute (U.S.A.)
Honorary Fellow	Inst. of Concrete Technology (U.K.)
Fellow	ASTM (U.S.A.)
Fellow	Engineering Institute of Canada (Canada)
Fellow	Canadian Society of Civil Engineering (Canada)
Honorary Member	Singapore Chapter, American Concrete Institute (Singapore)

EDITORIAL AFFILIATIONS:

Associate Editor	Canadian Journal of Civil Engineering (NRC Publication)
Member Editorial Board	Materials Journal, American Society of Civil Engineers (U.S.A.)
Member Editorial Board	International Journal of Cement Composites and Lightweight Concrete (U.K.)

PARTICIPATION IN NATIONAL AND INTERNATIONAL TECHNICAL COMMITTEES:

Chairman: ASTM C09.02.05 - Subcommittee Non-Destructive Testing of Concrete.

Chairman: CAC/ISO/TC 71 - On Concrete.

Member: CSA Committee on Concrete Materials for Offshore Structures.

Member: ASTM - Committee on C09 on Concrete. Also, Member of the Executive Committee.

Member: Several Technical Committees of the American Concrete Institute.

Member: CSA Steering Committee on Concrete.

Member: CSA Committee A23.1, on Concrete Materials; Also Member of the Executive (Chairman 1968-1978).

Member: Transportation Research Board/NRC, Washington, D.C. Committee on Mechanical Properties of Concrete (Chairman 1976-1982).

Member: Structures Advisory Committee, Canadian Highway Research Program (C SHRP)

PARTICIPATION IN NATIONAL AND INTERNATIONAL TECHNICAL REVIEW PANELS/ADVISORY BOARDS:

- i) Member: Technical review panel of Canadian Electrical Association (CEA) dealing with NDT of concrete and accelerated testing for alkali-aggregate reactivity. Total value of the projects \$350,000.
- ii) Member: Transportation Research Board/NRC, (U.S.A.) Technical panel on NDT of Concrete (project value \$200,000).
- iii) Advisor: Centre for By-Product Utilization, University of Wisconsin, Milwaukee, WI, (USA)

EDITORSHIP OF THE PROCEEDINGS OF INTERNATIONAL CONFERENCES:

Editor of Proceedings of the 2nd International Conference on Fly Ash, Slag, Silica Fume and Natural Pozzolans in Concrete, Madrid, Spain, 1986. (Two volumes, 1605 pp.)

Editor of Proceedings of the International Conference on Performance of Concrete in Marine Environment, St. Andrews, N.B., 1988. (One volume, 1737 pp.)

Editor of Proceedings of the 3rd International Conference on Fly Ash, Slag, Silica fume and Natural Pozzolons in Concrete, Trondheim, Norway, 1989. (Two volumes, 1709 pp.)

Editor of the proceedings of the 3rd International Conference on Superplasticizers, Ottawa, 1989. (One volume, 650 pp.)

AWARDS:

1. Received ASTM Award of Merit, 1989.
2. First recipient of the newly established Distinguished Services Award of the American Concrete Institute (Atlantic Chapter), Halifax, Canada, 1988.
3. Awarded Certificate of Appreciation by the Australian Organizing Committee of the Workshop on Fly Ash, Slag and Silica Fume for initiating the workshop, 1988.
4. Awarded special award by the University of Nuevo Leon, Monterrey, Mexico for outstanding contributions to the technology of concrete in Latin America, 1985.

CURRENT RESEARCH & OTHER ACTIVITIES:

The current research activity is directed at the utilization of supplementary cementing materials in concrete, developing engineering data for the use of mineral admixtures in controlling alkali aggregate reactions in concrete, development of high-strength concrete for offshore structures, monitoring long-term durability of various concretes at Treat Island Exposure Station and at Nanisivik, Baffin Island. In addition, research is directed at developing accelerated test methods for predicting potential reactivity of aggregates and identifying rock types which may be potentially reactive. Also, contract research is under way to develop echo-pulse techniques to monitor non-destructively the integrity of concrete structures.

Because of the emphasis on energy and resource conservation, investigations are in progress to develop alkali-activated blast-furnace slags and fly ashes. Research is also being continued to utilize non-ferrous slags in concrete.

- (a) The supplementary cementing materials being investigated include fly ash, blast-furnace slag, silica fume and non-ferrous slag. The development of high-volume fly ash concrete will help increase considerably the utilization of low-calcium fly ash. However, each fly ash is unique and its properties depend upon the source of coal being used. An engineering data base will have to be developed for each source of fly ash. Also, there is a problem of compatibility between fly ashes/cement and superplasticizers in this system. The fineness of fly ash also appears to have some effect on the performance of the above system. These problems need to be resolved. An international workshop on the subject is scheduled for Calgary in September 1990. (45% of time)
- (b) Activation of both ferrous- and non-ferrous slags is an exciting area and exploratory studies are under way. The best activators appear to be alkalies of various types. These have to be identified and data on long-term durability of concrete will have to be developed if industry is to accept the new binder systems for construction. In the area of non-ferrous slags, one of the serious drawbacks is the hardness of the material and very high grinding costs. A cost-shared project is in place with Falconbridge Ltd., Kidd Creek, Ontario on the use of ground granulated copper slag in mine backfill. Part of the research is a comminution study for the reduction of energy costs associated with grinding. Initial studies show that the use of a roller press would reduce grinding costs by as much as 25%. (5% of time)
- (c) Though silica fume is being used increasingly in concrete, there are several unresolved issues. One of these is the long-term strength development characteristics of silica fume concrete; the other related issue is the physical nature of the fume and how it should be incorporated in concrete i.e. whether it should be in slurry form, uncompacted form, compacted form or blended with cement. Investigations are in progress to obtain data for the former and discussions are being held with silica fume industry personnel to initiate a joint CANMET/industry project to resolve the latter issue. (10% of time)
- (d) The research in the area of alkali-aggregate reactivity has identified several rock types which may be potentially reactive and the evaluation of various accelerated tests to

predict expansion of reactive aggregates is underway; hopefully this will help standardization committees to develop a more reliable test method. There is a need to identify exact mechanisms which cause the undesirable problem of alkali-aggregate reactions. However, this is not easy and would need dedicated personnel and funds. The incorporation of mineral admixtures is one obvious way to control the above reactions, and CANMET studies in this respect will help. An international workshop to transfer CANMET technology in this area is being scheduled for Halifax in May 1990. (5% of time)

- (e) The installation of large concrete test specimens at Treat Island, Maine and Nanisivik, Baffin Island, is essential to determine long-term durability of concrete under field conditions. The experiments at Treat Island have been in progress for 11 years and at Nanisivik for only three years. It is believed that to get any meaningful results from outdoor exposure stations, a minimum exposure of 10 years is essential in order to eliminate the effects of seasonal variations, such as freezing and thawing cycles and ice formation. It is planned to continue the above studies for a total of 20 years when test specimens will be removed and tested destructively. In the interim, reports will issued periodically. The second International Conference of Durability of Concrete is scheduled for Montreal in August 1991. (6% of time)
- (f) In the area of NDT of concrete, the most promising techniques are impact echo and pulse echo. Contract research in pulse echo techniques has led to the development of powerful transducers and current research under an IRAP program is directed at developing a portable unit for field use. (2% of time)
- (g) Engineering data will be developed on the resistance of low to medium strength concrete to ice abrasion and impact. Based upon this and previous data on high-strength concrete, consideration will be given to modifying the test equipment to reduce the cost of testing. Mobil Oil Research, Dallas Texas is considering participating in this research. (2% of time)
- (h) Two cost recovery projects are in progress with a total value of about \$100,000. Also, assistance is being provided to Argentina in the fields of fly ash and blast-furnace slag under IRDC sponsorship. (5% of time)
- (i) Other duties (administration, personnel, etc.) (20% of time)

SIGNIFICANT CONTRIBUTIONS:**1. Contributions to the Development of Granulated Blast-Furnace Slag Industry in Canada**

Research initiated at CANMET in the mid 1980's led to the installation of a pilot plant to granulate blast-furnace slag at the Algoma Steel facility in Northern Ontario. The successful granulation of the slag and the excellent concrete making properties of the product led to the establishment of a \$13 million dollar slag granulation and grinding facility with a rated capacity of 150,000 metric tons per year in Blind River Ontario (1986). The granulated slag is now being used routinely as a binder material for mine backfill in the Sudbury basin area, and this in turn, has resulted in considerable savings in both energy and resources.

2. Development of High-Strength Lightweight Concrete

Semi-lightweight concretes (compressive strength > 70 MPa) have been developed using Canadian lightweight aggregates. These concretes incorporate superplasticizers and mineral admixtures and have very low water-to-cementitious materials ratios. This type of concrete is being considered for the construction of offshore oil drilling platforms off the coast of Newfoundland and in the Arctic.

3. Development of Superplasticized High-Volume Fly Ash Concrete

This development is considered to be a major breakthrough in the utilization of fly ash, a by-product of coal burning power stations, in concrete. As the name implies, this concrete incorporates large volumes of fly ash, and is highly superplasticized. The concrete develops low heat of hydration, and has superior mechanical properties compared to concrete made with portland cement alone. This concrete has been used in several commercial applications in Halifax and in the Ottawa area. Hydro Quebec, Montreal is seriously investigating the possibilities of using this concrete for the massive dams in the James Bay area.

4. Concrete Testing Methodology

One of the significant developments in this field has been the development of large automated testing equipment for measuring the resistance of concrete to ice impact and abrasion. This machine is the largest of its kind in the world and can test large concrete cylindrical specimens. Mobil Oil Research, Dallas, Texas has been utilizing the equipment on an exploratory basis, in preparation for the

design of the production platform which will exploit the Hibernia oil field off the coast of Newfoundland.

5. Technology Transfer

The research data and new technology developed at CANMET are quickly disseminated through the organization of national symposia, seminars, workshops and major international conferences. These meetings have become a very important element in transferring CANMET concrete technology and bringing overseas technology into Canada. During the period under review, four major international conferences and several workshops and seminars have been held both in Canada and overseas in the areas of supplementary cementing materials, concrete for offshore structures and marine environment, chemical admixtures, and alkali-aggregate reactivity.

REFEREED JOURNAL ARTICLES:

- Carette, G.G. and Malhotra, V. M. (1985): Performance of Concrete Incorporating Limestone Dust as Partial Replacement for Cement, American Concrete Institute (ACI) Journal, May-June, 363-371.
- Douglas, E. and Malhotra, V.M. (1985): Cementitious Properties of Non-ferrous Slags from Canadian Sources, ASTM Cement, Concrete and Aggregates, Vol. 7, No. 1, 3-14.
- Douglas, E., Malhotra, V.M. and Emery, J.J. (1985): Cementitious Properties of Non-Ferrous Slags from Canadian Sources ASTM Cement, Concrete and Aggregates, Vol. 7, No. 1, 3-14.
- Malhotra, V.M. (1986): Superplasticized Fly Ash Concrete for Structural Applications, ACI Concrete International, December, 28-31.
- Carette, G.G. and Malhotra, V.M. (1987): Characterization of Canadian Fly Ashes and Their Performance in Concrete, Canadian Journal of Civil Engineering, Vol. 14, No. 5, 667-682.
- Malhotra, V.M., Painter, K.A. and Bilodeau, A. (1987): Mechanical Properties and Freezing and Thawing Resistance of High-Strength Concrete Incorporating Silica Fume, ASTM Cement Concrete and Aggregates, Vol. 9, No. 2, 65-79.
- Johnston, C.D. and Malhotra, V.M. (1987): High-Strength, Semi-lightweight Concrete with up to 50% Fly Ash by Weight of Cement, ASTM Cement, Concrete and Aggregates, Vol. 9, No. 2, 101-112.

- Douglas, E., Wilson, H.S. and Malhotra, V.M. (1988): Production and Evaluation of a New Source of Granulated Blast-Furnace Slag, ASTM Cement, Concrete and Aggregates, Vol. 10, No. 2, 75-87.
- Giaccio, G. and Malhotra, V.M. (1988): Mechanical Properties and Freezing and Thawing Resistance of a High-Volume Fly Ash Concrete Made with ASTM Type I and III Cements, ASTM Cement, Concrete and Aggregates, Vol. 10, No. 2, 88-95.
- Wilson, H.S. and Malhotra, V.M. (1988): Development of High-strength Lightweight Concrete for Structural Applications, International Journal of Cement Composites and Lightweight Concretes, Vol. 10, No. 2, 79-90.
- Malhotra, V.M. and Painter, K. (1989): Early-Age Strength Properties, and Freezing and Thawing Resistance of Concrete Incorporating High-Volumes of ASTM Class F Fly Ash, International Journal of Cement Composites and Lightweight Concrete, Vol II, No. 1, 37-46.
- Malhotra, V.M. (1989): Mechanical Properties and Freezing and Thawing Resistance of Concrete Incorporating a Ground Granulated Blast-Furnace Slag, Canadian Journal of Civil Engineering, Vol. 16, No. 2, 140-156.
- Douglas, E. and Malhotra, V.M. (1989): Ground Granulated Blast-Furnace Slag for Cementing Mine backfill: Production and Evaluation, CIM Bulletin V. 82, No. 929.
- Langley, W.S., Carette, G.G. and Malhotra, V.M. (1989): Structural Concrete Incorporating High Volumes of ASTM Class F Fly Ash, ACI Journal of Materials, September-October, Vol. 86, No. 5.

REFEREED SPECIAL PUBLICATIONS OF AMERICAN CONCRETE INSTITUTE AND ASTM:

- Carette, G.G. and Malhotra, V.M. (1985): Performance of Dolostone and Limestone Concretes at Sustained High Temperatures, ASTM STP 858, 38-67.
- Malhotra, V.M. (1986): Mechanical Properties, and Freezing and Thawing Resistance of Non-Air Entrained and Air Entrained Condensed Silica Fume Concrete Using ASTM Test C666 Procedures A and B, ACI SP 91, 1069-1094.
- Malhotra, V.M., Carette, G.G. and Bremner, T.W. (1987): Durability of Concrete Containing Supplementary Cementing Materials in Marine Environment, ACI SP 100, Vol. 2, 1227-1259.

- Malhotra, V.M. (1987): Superplasticizers, Pozzolans, and Granulated Blast-Furnace Slags in Concrete: A Review, ACI SP 104, 63-88.
- Malhotra, V.M., Carette, G.G. and Bremner, T.W. (1988): Current status of CANMET's Studies on the Durability of Concrete Containing Supplementary Cementing Materials in Marine Environment, ACI SP 109, 31-72.
- Bisailon, A. and Malhotra, V.M. (1988): Permeability of Concrete using a Uniaxial Water-Flow Method, ACI SP 108, 175-194.
- Nawwar, A.M. and Malhotra, V.M. (1988): Development of a Test Method to Determine the Resistance of Concrete to Ice Abrasion and Impact, ACI SP 109, 401-426.
- Carette, G.G., Malhotra, V.M., Bedard, C. and Benedictis, V. (1988): Development of Heat-Curing Cycles for Portland Cement - Fly Ash Concrete for the Precast Industry, ACI SP 91, 249-272.
- Sivasundaram, V., Carette, G.G. and Malhotra, V.M. (1989): Properties of Concrete Incorporating Low Quantity of Cement and High Volumes of Low Calcium Fly Ash, ACI SP 114, 45-72.
- Malhotra, V.M., Wilson, H.S., and Painter K. (1989): Performance of Gravelstone Concrete Incorporating Silica Fume at Elevated Temperatures, ACI SP 114, 1051-1076.
- Soles, J.A., Malhotra, V.M. and Chen, C. (1989): CANMET Investigations of Supplementary Cementing Materials For Reducing Alkali-Aggregate Reactions: Part I, Granulated/Pelletied Blast-Furnace Slags, ACI SP 114, 1637-1656.
- Malhotra, V.M. (1989): Superplasticizers: A Global Review with Emphasis on Durability and Innovative Concretes, ACI SP 119, 1-18.
- Samarai, M.A., Ramakrishnan, V. and Malhotra, V.M. (1989): Effect of Retempering with Superplasticizers on Properties of Fresh and Hardened Concrete Mixed at Higher Ambient Temperatures, ACI SP 119, 273-296.

REFEREED CONFERENCE PROCEEDINGS:

- Carette, G.G., Malhotra, V.M. and Aitcin, D.C. (1985): Mechanical Properties of Portland Cement Concrete Incorporating Blast-Furnace Slag and Condensed Silica Fume, Proceedings, ACI/RILEM Symposium on Pozzolans, Slags and Chemical Admixtures, Monterrey, Mexico, 395-403.
- Malhotra, V.M. (1985): Developments in Materials Technology: A State-of-the-Art, Proceedings, IEP-CSCE-VET International Colloquium: "Concrete in Developing Countries, Vol. 1, 3-39.
- Malhotra, V.M. (1985): Non-Destructive Testing for Concrete Strength, Proceedings, IEP-CSCE-VET International Colloquium: "Concrete in Developing Countries", Vol. 1, 263-276.
- Malhotra, V.M. (1987): In-situ Non-destructive Testing for Concrete: A Review, Proceedings of the 2nd International Conference on Concrete Technology for Developing Countries, Bombay, India, 27-41.
- Malhotra, V.M. (1987): CANMET Investigations in the Development of High-Strength Lightweight Concrete, Proceedings, International Conference on the Utilization of High-Strength Concrete, Stavanger, Norway, 1-15.
- Malhotra, V.M. (1987): Role of Supplementary Cementing Materials in Concrete, IX Inter-American Conference on Materials Technology, Santiago, Chile, 555-558.
- Soles, A., Malhotra, V.M., and Suderman, R. (1987): The Role of Supplementary Cementing Materials in Reducing the Effects of Alkali-Aggregate Reactivity, CANMET Investigations, Proceedings of the 7th International Conference on Alkali-Aggregate Reactions in Concrete, 77-82.
- Sivasundaram, V., Carette, G.G. and Malhotra, V.M. (1987): Superplasticized High-Volume Fly Ash System to Reduce Temperature Rise in Mass Concrete, Proceedings, Eight International Coal Ash Utilization Symposium, Washington, D.C., June, Vol. 2, 13 pp.
- Malhotra, V.M. (1988): Use of Fly Ash, Slag and Silica Fume in North America and Europe, Proceedings, International Workshop on the Use of Fly Ash, Slags, Silica Fume and Other Siliceous Materials in Concrete, Sydney, Australia, 23-55.
- Malhotra, V.M. (1988): New Materials for Quality Concrete, Proceedings, Fifth Canadian Building and Construction Congress, Montreal, Canada, 163-167.

Bremner, T.W., Carette, G.G. and Malhotra, V.M. (1989): Role of Supplementary Cementing Materials in Concrete for Marine Environment, Proceedings, 2nd International Conference on Some Aspects of Admixtures and Industrial by-Products on the Durability of Concrete, University of Chalmers, Goteborg, Sweden, June, 23-32.

Malhotra, V.M. (1989): Durability of Concrete Incorporating High-Volume of low calcium (ASTM class F) Fly Ash, Proceedings, 2nd International Conference on Some Aspects of Admixtures and Industrial by-products on the Durability of Concrete, June 25-27, 93-104.

BOOKS:

Malhotra, V.M. (Editor) (1987) "Supplementary Cementing Materials", CANMET Special Publication SP 86-8E, 428 pp. (Price \$18.50)

AUTHOR IN OTHER BOOKS:

Malhotra, V.M., Ramachandran, V.S., Feldman, R.F., Aitcin, Pierre-Claude (1987) "Condensed Silica Fume in Concrete", CRC Press Boca Raton, 219 pp. (Price = \$160.00 U.S.).

Berry, E.E. and Mahotra, V.M. (1985) "Fly Ash in Concrete", CANMET Special Publications SP 85-3, 178 pp. (Price \$7.50)

ORAL PRESENTATIONS - INTERNATIONAL:

1985

Malhotra, V.M. "Mechanical Properties of Portland Cement Concrete Incorporating Blast-Furnace Slag and Condensed Silica Fume"; Invited presentation at the ACI/RILEM Symposium on "Technology of Concrete when Pozzolans, Slags and Chemical Admixtures are used"; Monterrey, Mexico, March 10-15, 1985 (All expenses covered by the host organization).

Malhotra, V.M. was invited by the Norwegian Concrete Institute and Scancem A/C, Norway, to present a state-of-the-art paper on Concrete Technology at the meetings of the Institute and at SCANCEN A/C, Norway, May 1985 (All expenses paid by the host organizations).

Malhotra, V.M. was invited by CSNDT, Toronto, to conduct a U.N. sponsored 5-day course on "NDT of Concrete" at Buenos Aires, Argentina, November 4 to 8, 1985 (All expenses and fees paid by the host organizations on partial cost recovery basis).

Malhotra, V.M. was invited by the University of Wisconsin - Extension Department to participate in a program "Concrete Testing by NDT methods"; Milwaukee. November 1985. (All expenses covered by the host organization).

Malhotra, V.M. visited Dallas, Texas, to address a dinner meeting of the ACI Chapter, November 21, 1985 (All expenses paid by the host organization).

Malhotra, V.M. "Non-Destructive Testing of Concrete"; Invited presentation at an International Colloquium on "Concrete in Developing Countries"; Lahore, Pakistan, December 16-18, 1985.

Malhotra, V.M. "Development in materials Technology: A State-of-the-Art"; Invited presentation at an International Colloquium on "Concrete in Developing Countries"; Lahore, Pakistan, December 16-18, 1985 (All expenses paid by CSCE and CIDA).

1986

Malhotra, V.M. was invited by the University of Wisconsin - Extension Department to participate in a program "Concrete Testing by NDT Methods", Milwaukee, 1986. (All expenses covered by the host organization.)

Malhotra, V.M. was invited by the Central New York Chapter of the American Concrete Institute to address a dinner meeting on "NDT of Concrete"; Syracuse, N.Y., 1986. (All expenses paid by the host organization.)

Malhotra, V.M. "Freezing and Thawing Resistance of High-Strength Concrete incorporating Silica fume"; invited presentation at the Transportation Research Board Annual Meeting, Washington, D.C., January 20-24, 1986.

Malhotra, V.M. "High-Volume Fly Ash Concrete", Presented at the 2nd CANMET/ACI International Conference on Fly Ash, Slag, Silica Fume and Natural Pozzolans in Concrete; Madrid, Spain, April 22-25, 1986.

Carette, G.G. and Malhotra, V.M. "Characterization of Canadian Fly Ashes and Their Performance in Concrete"; Presented at the 2nd CANMET/ACI International Conference on Fly Ash, Slag, Silica fume and Natural Pozzolans in Concrete"; Madrid, Spain, April 22-25.

Malhotra, V.M., Carette, G.G. and Bremner, T.W. "Durability of Concrete Containing Supplementary Cementing Materials in Marine Environment--Status Report as of 1985"; Presented at the 2nd International Conference on Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete, Madrid, Spain, April 22-25, 1986.

Cossette, M., Douglas, E. and Malhotra, V.M. "Development of A/C Cooling Tower Fill with Improved Durability"; invited presentation at the First International Conference on Asbestos Cement, May 4-7, 1986, Cannes, France.

Roots, T., Nawwar, A.M. and Malhotra, V.M. "Development of a Test Method to Determine the Resistance of Concrete to Ice Abrasion and/or Impact"; Presented at CSCE/CANMET International Workshop on Concrete for Offshore Structures, September 10-11, 1986, St. John's, Nfld. (Presented by T. Roots).

Bisailon, A. and Malhotra, V.M. "Reproducibility of a New Technique for Measuring the Permeability of Concrete"; Presented at the CSCE/CANMET International Workshop on Concrete for Offshore Structures, September 10-11, 1986, St. John's, Nfld.

1987

Malhotra, V.M., Carette, G.G., and Bremner, T.W., "Durability of Concrete Containing Supplementary Cementing Materials in Marine Environment"; Mathers' International Conference on Durability of Concrete, Atlanta, April 28 - May 1, 1987.

Malhotra, V.M., Painter, K.E., and Bilodeau, A., "Mechanical Properties and Freezing and Thawing Resistance of High-Strength Concrete Incorporating Silica Fume"; Presented at the International Workshop on Condensed Silica Fume in Concrete; Montreal, May 4, 1987.

Carette, G.G., Malhotra, V.M., and Aitcin, P.C., "Preliminary Data on Long-Term Strength Development of Condensed Silica Fume Concrete"; Presented at the International Workshop on Condensed Silica Fume in concrete, Montreal, May 4, 1987.

Malhotra, V.M. "CANMET Investigations in the Development of High-Strength Lightweight Concrete"; invited presentation at the International Conference on the Utilization of High-Strength Concrete; Stavanger, Norway, June 15-18, 1987.

Malhotra, V.M. "Role of Supplementary Cementing Materials in Concrete"; invited presentation at the IX Interamerican Conference on Materials Technology, Santiago, Chile, October 5-9, 1987.

Malhotra, V.M., Carette, G.G., Bremner, T.W. "Durability of Blast-Furnace Slag Concrete in Marine Environment"; International Workshop on Granulated Blast-Furnace Slags in Concrete; Toronto, Ontario, Oct. 22-23, 1987.

Soles, J.A., Malhotra, V.M., and Chen, H. "CANMET Investigations of Supplementary Cementing Materials for Reducing Alkali-Aggregate Reactions; Part I - Granulated Pelletized Blast Furnace Slag"; International Workshop on Granulated Blast-Furnace Slags in Concrete, Toronto, Ontario, Oct. 22-23, 1987.

Malhotra, V.M., "Superplasticizers, Pozzolans, and Granulated Blast Furnace Slags in Concrete: A Review"; invited presentation at the ACI Tuthill International Symposium on Concrete, ACI Fall Meeting, Seattle, WA, Nov. 9-12, 1987.

Malhotra, V.M. and G.G. Carette. "Long-term Strength Development of Condensed Silica Fume Concrete"; ACI Tuthill International Symposium on Concrete, ACI Fall Meeting, Seattle, WA, Nov. 9-12, 1987.

Bisaillon, A. and Malhotra, V.M., "Permeability of Concrete Using a Uniaxial Water-Flow Method"; ACI Tuthill International Symposium on Concrete, ACI Fall Meeting, Seattle, WA, Nov. 9-12, 1987.

1988

Langley, W.S., Carette, G.G. and Malhotra, V.M. "Structural Concrete Incorporating High-Volumes of ASTM Class F Fly Ash"; invited presentation TRB Annual Meeting, Washington, DC, January 1988.

Malhotra, V.M. "Freezing and Thawing Resistance of Superplasticized Concrete"; invited presentation TRB Annual Meeting, Washington, DC, January 1988.

Malhotra, V.M. "Use of Fly Ash, Slag and Silica Fume in North America and Europe"; invited presentation at the International Workshop on the Use of Fly Ash, Slag, Silica Fume and Other Silicious Materials in Concrete, Sydney, Australia, July 1988.

Malhotra, V.M. "Role of Fly Ash, Slag and Silica fume in Making better Concrete"; invited 2nd Annual Lecture at the Meeting of the ACI Singapore Chapter, Singapore, July 1988.

Malhotra, V.M., Carette, G.G., and Bremner, T.W. "Current Status of CANMET Studies on the Durability of Concrete Containing Supplementary Cementing Materials in Marine Environment"; 2nd CANMET/ACI International Conference on Performance of Concrete in Marine Environment, St. Andrews, N.B., August 1988.

Nawwar, A.M. and Malhotra, V.M. "Development of a Test Method to Determine the Resistance of Concrete to Ice Abrasion and/or Impact"; 2nd CANMET/ACI International Conference on Performance of Concrete in Marine Environment, St. Andrews, N.B., August 1988.

Malhotra, V.M., gave a series of invited lectures on Concrete Technology at the Structural Engineering Research Centre, Madras, India, August 1988.

Malhotra, V.M., gave a series of invited lectures at the National Council for Cement and Building Materials, New Delhi, India, August 1988.

Malhotra, V.M. "Chloride Ion Permeability of High-Volume Fly Ash Concrete"; Fall meeting of the American Concrete Institute, Houston, October 1988.

1989

Malhotra, V.M. "Laboratory and Field Evaluation of Freezing and Thawing Tests"; invited presentation at the Ben C. Gerwick Jr. International Symposium on Durability of Concrete in Marine Environment, University of Berkeley, Berkely, CA, January 16-17, 1989.

Sivasundaram, V., Carrette, G.G, and Malhotra, V.M. "Properties of Concrete Incorporating Low Quantity of Cement and High Volumes of Low-calcium Fly Ash"; 3rd International Conference on Fly Ash, Slag, Silica Fume and Natural Pozzolons in Concrete, Trondheim, Norway, June 19-24, 1989.

Malhotra, V.M., Wilson, H.S. and Painter K.E. "Performance of Gravelstone Concrete Incorporating Silica Fume at Elevated Temperatures"; 3rd International Conference on Fly Ash, Slag, Silica Fume and Natural Pozzolons in Concrete, Trondheim, Norway, June 19-24, 1989.

Soles, J.A., Malhotra, V.M. and Chen H. "CANMET Investigations of Supplementary Cementing Materials for Reducing Alkali-Aggregate Reactions"; 3rd International Conference on Fly Ash, Slag, Silica Fume and Natural Pozzolons in Concrete, Trondheim, Norway, June 19-24, 1989.

Malhotra, V.M. "Durability of Concrete Incorporating High Volume of Low-Calcium (ASTM Class. F.) fly ash"; invited presentation at the 2nd International Seminar on Durability of Concrete: Aspects of Admixtures and Industrial by-products, Chalmers University of Technology, Goteborg, Sweden, June 26-27, 1989.

Bremner, T., Carette, G. and Malhotra, V.M. "Supplementary Cementing Materials and the Performance of Concrete in Marine Environment"; invited presentation at the 2nd International Seminar on Durability of Concrete: Aspects of Admixture and Industrial by-products, Chalmers University of Technology, Goteborg, Sweden, June 26-27, 1989.

Malhotra, V.M. "High-Volume Fly Ash Concrete"; invited presentation at one-day seminar organized by the Center for By-Products Utilization, University of Wisconsin, Milwaukee, WI., August 25, 1989.

Malhotra, V.M. "Superplasticizers: A Global Review with Emphasis on Durability and Innovative Concrete"; Third International Conference on Superplasticizers and Other Chemical Admixtures in Concrete, Ottawa, October 4-6, 1989.

Samarai, M.A., Ramakrishnan, V., and Malhotra, V.M. "Effect of Retempering with Superplasticizers on Properties of Fresh and Hardened Concrete Mixed at Higher Ambient Temperatures"; Third International Conference on Superplasticizers and Other Chemical Admixtures in Concrete, Ottawa, October 4-6, 1989.

Malhotra, V.M., G.G. Carette, A. Bilodeau and D. Dibble. "Fiber Reinforced, High-Volume Fly Ash Shotcrete for Controlling Aggressive Leachates from Exposed Rock Surfaces and Mine Tailings"; Third International Conference on Superplasticizers and Other Chemical Admixtures in Concrete, Ottawa, October 4-6, 1989.

ORAL PRESENTATIONS - CANADA:

1986

Malhotra, V.M. was invited by the Eastern Ontario Region and Quebec Chapter of ACI to be a member of a panel on "Superplasticizers in Concrete"; Ottawa, October 1986.

Malhotra, V.M. was invited by the Industrial Materials Research Institute to present a Seminar on "NDT of Concrete", Montreal, November 19, 1986. (All expenses covered by the host Institute.)

Malhotra, V.M. presented a paper on "High-Volume Fly Ash in Concrete" at a CANMET sponsored seminar on N.S. Fly Ashes, Halifax, November 28, 1986.

1987

Malhotra, V.M. "CANMET Investigations into the Development of High-Volume Fly Ash Concretes"; Presented at the CANMET-sponsored Workshop on Fly Ash in Concrete held at Halifax, November 6, 1987.

1988

Malhotra, V.M. "CANMET Researches in Concrete Technology"; Invited presentation at the Annual Meeting of the ACI Atlantic Chapter, Moncton, N.B., February 1988.

Malhotra, V.M. "New Materials for Quality Concrete"; Invited presentation at the Fifth Building and Construction Congress, Montreal, Canada, November 1988.

Malhotra, V.M. "Needed Methodology for Testing Concrete Repair Materials"; Invited presentation at the ACI Quebec Chapter, Montreal, November 1988.

CANMET PUBLICATIONS:

Douglas, E. and Malhotra, V.M. (1985) "A Review of the Properties and Strength Development of Portland Cement - Non-Ferrous Slag Binders", CANMET Report 85-7, 23 pp.

Douglas, E. and Malhotra, V.M. (1988) "Compilation of abstracts of papers from recent international conferences and symposia on condensed silica fume in concrete"; CANMET Report SP88-14E, Energy, Mines and Resources Canada, Ottawa.

Douglas, E. and Malhotra, V.M. (1988) "Compilation of abstracts of papers from recent international conferences and symposia on ferrous and non-ferrous slags in concrete"; CANMET Report SP88-13E.

Sivasundaram, V. and Malhotra, V.M. (1988) "Compilation of abstracts of papers from recent international conferences and symposia on fly ash in concrete"; CANMET Special Publication SP87-6E, 70 pp., 1988.

DIVISIONAL REPORTS:

Total number of reports issued = 10 Some typical examples are as follows:

Malhotra, V.M., Carrette, G.G. Bilodeau, A., and Dibble, D. (1989) "Fibre-Reinforced, High Volume Fly Ash Shotcrete for Controlling Aggressive Leachates from Exposed Rock and Mine Tailings", MSL Division Report, MSL 89-70(OP), 16 pp. CANMET, Energy, Mines and Resources Canada, Ottawa.

Malhotra, V.M. (1989) "Recent Developments in Concrete Technology", MSL Division Report, MSL 89-92(OP), 13 pp. CANMET, Energy, Mines and Resources, Canada, Ottawa.

Malhotra, V.M. (1989) "Mechanical Properties of High-Strength Semi-Lightweight Concrete Incorporating Fly Ash and Silica Fume", MSL Division Report, MSL 89-82(OP & J), 24 pp. CANMET, Energy, Mines and Resources, Canada, Ottawa.

PARTICIPATION IN NATIONAL/INTERNATIONAL MEETINGS (other than oral presentations):

1986: Chairman of the Organizing Committee and the Technical Program of the 2nd International Conference in the Use of Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete, held in Madrid, Spain, 1986 (attendance = 450).

1986: Member of the Organizing Committee of a joint symposium (NCCL & RILEM) on the use of "Vegetable Plants and Other Fibers as Building Materials" held in Baghdad, Iraq, October 7-9, 1986.

Chairman of the one-day CANMET sponsored seminar on "Research needs in Silica Fume" held in Ottawa, April 9, 1986. (Attendance restricted to 25 people.)

1987: Chairman of the Organizing Committee of the two-day International Workshop on the "Use of Silica Fume in Concrete" held in Montreal, May 4-5, 1987. (attendance: 185)

Member of the Organizing Committee of the Mathers' International Conference on "Durability of Concrete" held in Atlanta, April 28 -May 1, 1987.

Member of the International Steering Committee for a symposium on "Fibre Reinforced Concrete" held in Madras, India, December 16-19, 1987.

1988: Chairman of the Organizing Committee and the Technical Programs of the 2nd International Conference on Performance of Concrete in Marine Environment, St. Andrews, August 1988. (185 people attended the conference).

Chairman of the Canadian Advisory Committee for the Australian Workshop on Fly Ash, Silica Fume and B.F. Slag, Sydney, Australia, July 1988. (220 people attended the conference).

Chairman of the MSL Seminar on Role of Supplementary Cementing materials in Mining Industry, Sudbury, Ontario, September 1988. (65 people attended the seminar).

- 1989: Chairman, Organizing Committee and the technical program of the 3rd International Conference in the Use of Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete held in Trondheim, Norway, June 1989. (405 people attended the conference).
- 1991: Chairman, Organizing Committee and the technical program of the 2nd International Conference on Durability of Concrete to be held in Montreal in August 1991.
- 1991: Chairman of the Steering Committee of the American Concrete Institute Committee to organize an International Conference on Concrete Technology in Singapore in 1992.
- 1992: Member of the Scientific Committee of the 9th International Conference on Chemistry of Cement to be held in India in 1992.

CERAMICS

CURRICULUM VITAE

NAME: A.K. Kuriakose

DEGREES: Ph.D. 1961, University of Madras
 M.A. 1955, " "
 B.Sc. 1953, " "

EXPERTISE:

Ceramics: Powder synthesis, processing and characterization; sintering; hot-pressing; arc furnace fusion and casting; toughened ceramics; abrasives; silicon carbide powder, whisker and single crystals; hydrogen and sodium conducting solid electrolytes; ceramic microstructure; mechanical properties of ceramics.

High Temperature Chemistry: Behaviour of materials at high temperatures; high temperature kinetics; reactions of elemental fluorine; thermal analysis; materials synthesis; mass spectrometry.

High Pressure Chemistry: Synthesis and phase diagrams.

CAREER:

1989 - present	Research Scientist 3, CANMET
1981 - 1989	Research Scientist 2, CANMET
1975 - 1981	Supervisor of Materials Research, Norton Co.
1969 - 1975	Senior Research Engineer, Norton Co.
1966 - 1969	Research Engineer, Norton Co.
1965 - 1966	Postdoctoral Fellow, National Research Council Canada.
1963 - 1965	Project Associate and Research Fellow, Rice University.
1962 - 1963	Project Associate, University of Wisconsin.
1961 - 1962	Research Associate, Illinois Institute of Technology.
1957 - 1960	Research Assistant, Loyola College, University of Madras.
1956 - 1957	Demonstrator in Chemistry, Loyola College, University of Madras.
1955 - 1956	Lecturer in Chemistry, Kerala University.

PROFESSIONAL AFFILIATIONS:

Canadian Ceramic Society
The American Ceramic Society
Sigma-Xi

AWARDS: Ceramographic Award, Canadian Ceramic Society, 1987.
Patent Award, CANMET, 1988.

CURRENT RESEARCH & OTHER ACTIVITIES:

- (a) Toughened Ceramics: A joint CANMET/industry co-operative program aimed at product improvement and cost reduction is continuing. The main effort is on zirconia-toughened materials because these have the highest potential to produce ceramics with high strength and fracture toughness at moderate costs. (20% of time)
- (b) High Temperature Strength Ceramics: A joint CANMET/industry co-operative program on silicon carbide is also continued. Silicon carbide is one of the very few materials that have high strength at temperatures as high as 1600°C; but is extremely difficult to fabricate. Most of the processes known to-day make use of sintering aids for the sintering of the powder. However, these sintering aids limit the highest temperature at which the materials can perform. One of the objectives of this program is to find ways of sintering high purity silicon carbide powders without or with minimum use of other sintering aids. (20% of time)
- (c) Hydrogen Conducting Solid Electrolytes: (i) A co-operative program with industry in the development of devices for hydrogen sensing is in progress. (5% of time). (ii) CUICAC Program to develop these materials further. (5% of time)
- (c) Refractories for steel making: In cooperation with Canadian Iron and Steel Research Association (CISRA) and Ecole Polytechnique the refractory failure mechanisms in various iron and steel making furnaces and ladles are to be investigated. (10% of time)
- (d) Setting up equipment and facilities for testing strength and creep of advanced ceramics at high temperatures and for sintering of silicon carbide. (10% of time)
- (e) Continuing education. (5% of time)

- (f) Committee duties including refereeing & reviewing manuscripts and grant proposals. (5% of time)
- (g) Administrative, including contracts, technology transfer and preparation time. (5% of time)
- (h) Cost recovery: Visiting and corresponding with companies and performing related research work. (5% of time)
- (i) Contribution to other research programs of the group. (10% of time)

SIGNIFICANT CONTRIBUTIONS:

It should be mentioned that the five contributions given below are results of team work involving several colleagues and/or external cooperators.

1. Development of Hydrogen Conducting Ceramics

The major applications of these materials are in hydrogen sensors, tritium pumps, steam electrolyzers and energy-efficient fuel cells. At CANMET a new approach was conceived to produce the only strong hydrogen conducting ceramic solid electrolyte available in the world to-day. The product has been patented by CANMET and it is known under the trade mark "Hyceram". There has been an international demand for this product; requests have been received from scientists in Denmark, West Germany, Italy, Israel, Mexico, Japan, U.S.A. and U.K. to obtain samples. AECL is developing a simple, reliable and durable tritium decontamination device using Hyceram. Collaborative work is now underway with Nova Systems of Hamilton for the development of sensors for hydrogen analysis in blast furnace gases.

2. Beta"-Alumina

This is the material used as sodium ion membrane in sodium-sulphur batteries for electric vehicles and in high efficiency sodium thermoelectric generators. An industrially feasible, new spray-drying process was developed to produce high quality beta"-alumina precursor powders. The method was successfully employed by Almax Industries in manufacturing their beta-alumina tubes for use in thermoelectric generators. This represented part of the technology transferred to Almax Industries for which CANMET received the 1986 Silver Medal in the Canada Award for Excellence. The impact of this new method is significant not only for Almax Industries for the manufacture of thermoelectric generators,

but also for Powerplex Industries, a Division of Magna International, for their electric vehicle program.

3. Toughened Ceramics - Zirconia Toughened Alumina and Mullite

A program was initiated for the development of zirconia-toughened alumina and mullite in 1985. These systems were chosen based on cost-performance advantage. To transfer this technology to industry, a "Request for Proposal" to work on this material was sent out to prospective Canadian industries and institutions. The six responses that were received showed the high level of industrial interest in the product. The contract was awarded to the Electrofuel Manufacturing Company and they successfully completed the cooperative work. Currently they are manufacturing and marketing cutting tools made of zirconia-toughened alumina (ZTA).

4. Silicon Carbide Ceramics

Silicon carbide is one of the few materials that is claimed to retain its strength to about 1600°C in an oxidizing atmosphere, e.g. internal combustion engines, high temperature gas turbines and the aerospace industry.

A program was initiated at CANMET for the synthesis and exploitation of silicon carbide. The fabrication of silicon carbide ceramics requires highly reactive powders, and ultra high quality silicon carbide powders are not readily available in the market. A direct synthetic method was devised for the production of highly pure and highly reactive silicon carbide powder by reacting finely divided silica with finely divided carbon.

Ceramics Kingston is a collaborator on this project. They have seconded a scientist to CANMET to develop the manufacturing process. They are also building manufacturing facilities in Kingston for the production of silicon carbide. Other companies that are interested in silicon carbide are Electrofuel Manufacturing Company and Almax Industries. Their applications are, respectively, in heat engine parts and electrical systems.

5. Iron Ore Processing

In the pelletizing operation, bentonite is added to develop strength. This, however, causes alkali and silica contamination problems. At CANMET, several organic binders were examined as possible bentonite substitutes. Most of these provided cold pellet strength, but not after induration. The strength was lost through binder burn-off. However, a partial substitution of the bentonite with an

organic binder, or the addition of calcium carbonate with organic binder imparted the required strength on induration. As a member of the Iron Ore Technical Task Force, the technical information has been passed on to the various participating iron ore processors. Based on the results, the Iron Ore Company of Canada and Dofasco have been experimenting with organic additives.

EXTERNALLY REFEREED JOURNAL PAPERS:

- Wheat, T.A., Ahmad, A., Kuriakose, A.K. & Canaday, J.D. (1985): Hydrogen-ion Conducting Solids. J. Can. Ceram. Soc. 54, 32-39.
- Canaday, J.D., Kuriakose, A.K., Ahmad, A. & Wheat, T.A. (1986): Device Applications of Hydrogen-Conducting Solid Electrolytes. J. Can. Ceram. Soc. 55, 34-37.
- Kuriakose, A.K., Wheat, T.A., Ahmad, A. & Canaday, J.D. (1987): Polycrystalline Sodium-Potassium Beta/beta"-Alumina. J. Solid State Chem. 69, 312-319.
- Ahmad, A., Wheat, T.A., Kuriakose, A.K., Canaday, J.D. & McDonald, A.G. (1987): Dependence of the Properties of Nasicons on Their Composition and Processing. J. Solid State Ionics 24, 89-97.
- Canaday, J.D., Wheat, T.A., Ahmad, A. & Kuriakose, A.K. (1987): Gas Phase Relations for Protonic Solid-Electrolyte Fuel Cells. J. Appl. Electrochem. 17, 545-551.
- Canaday, J.D., Wheat, T.A., Kuriakose, A.K. & Ahmad, A. (1987): A Polarization Model for Protonic Solid Electrolyte Fuel Cells. Int. J. Hydrogen Energy 12, 151-157.
- Ahmad, A., Kuriakose, A.K., Wheat, T.A. & Canaday, J.D. (1987): Physical Characteristics of Na and (Na-K), beta-beta" Aluminas. J. Can. Cer. Soc. 56, 58-63.
- Gulens, J., Longhurst, T.H., Kuriakose, A.K. & Canaday, J.D. (1988): Hydrogen Electrolysis using a Nasicon Solid Protonic Conductor. J. Solid State Ionics 28-30, 622-626.
- Quon, D.H.H., Wang, S.S.B., Aota, J., Wheat, T.A., Kuriakose, A.K. & Torrie, G. (1989): Hydrothermal Synthesis of Zirconia and the Preparation of Zirconia-Mullite Composites. Interceram, No.3, 15-17.

Canaday, J.D., Kuriakose, A.K., Wheat, T.A., Ahmad, A., Gulens, J. & Hildebrandt, B.W. (1989): Bonded Solid Proton Conductor/Platinum Electrochemical Cells. Solid State Ionics, 35, 165-175.

Gulens, J., Hildebrandt, B.W., Canaday, J.D., Kuriakose, A.K., Wheat, T.A. & Ahmad, A. (1989): Influence of Water on Electrochemical Response of a Bonded Protonic Conductor. Solid State Ionics, 35, 45-49.

Chehab, S., Canaday, J.D., Kuriakose, A.K., Wheat, T.A. & Ahmad, A. (1989): A Hydrogen Sensor Based on Hydronium Nasicon. Submitted for publication in Solid State Ionics.

Canaday, J.D., Chehab, S., Kuriakose, A.K., Wheat, T.A. & Ahmad, A. (1989): Protonic Conductivity of the Bonded Hydronium-Nasicon/Platinum Electrode System. Submitted for publication in Solid State Ionics.

REFEREED CONFERENCE PROCEEDINGS:

Kuriakose, A.K., Quon, D.H.H., Bell K.E. & Soles, J.A. (1986): Extrusion and Induration of Iron Ore using Polymers and Calcium Carbonate as Plasticizer/Bond. Process Mineralogy VI: Proceedings of the Sixth International Conference on Process Mineralogy, New Orleans, La., (Hagni, R.D. ed.), The Met. Soc. Inc., Penn., 485-498.

PUBLISHED ABSTRACTS:

Canaday, J.D., Ahmad, A., Wheat, T.A. & Kuriakose, A.K. (1985): Polarization Models for Protonically Conducting Solid Electrolyte Fuel Cells. Can. Clay and Ceram. 58(1), 20.

Kuriakose, A.K., Quon, D.H.H. & Bell, K.E. (1985): Preparation of Iron Ore Pellets by Extrusion. J. Metals 37(11), 97.

Canaday, J.D., Wheat, T.A., Kuriakose, A.K. & Ahmad, A. (1985): A Microcomputer System for Fuel Cell Experiments. J. Electrochem. Soc. Ext. Abs. 85(1), 538-39.

Ahmad, A., Wheat, T.A., Canaday, J.D. & Kuriakose, A.K. (1985): Electrical Characterization of Ceramic Electrolytes. Can. Clay and Ceramics 58(1), 21.

Kuriakose, A.K., Wheat, T.A., Ahmad, A. & Canaday, J.D. (1986): Some Properties of Hydronium Zirpsios. Can. Clay and Ceramics Quart. 59(1), 24.

Canaday, J.D., Kuriakose, A.K., Ahmad, A. & Wheat, T.A. (1986): Electrical Measurements on Protonic Solid Electrolyte Cells. Can. Clay and Ceramics Quart. 59(1), 21.

Kuriakose, A.K., Wheat, T.A. & Hanson, A.J. (1987): Synthesis of Silicon Carbide. Can. Clay and Ceramics Quart. 60(1), 26.

Ahmad, A., Kuriakose, A.K., Wheat, T.A. & Canaday, J.D. (1987): Dependence of the Properties of Na and (Na-K) Beta/Beta"- Aluminas. Can. Clay and Ceramics Quart. 60(1), 23.

Canaday, J.D., Kuriakose, A.K., Wheat, T.A. & Ahmad, A. (1987): Electrochemical Aspects of Protonic Solid Electrolyte Cells. Can. Ceram. Quart. 60(1), 22.

Ghosh, D., Jacobs, J., Das Gupta, S., Wheat, T.A., Kuriakose, A.K. & Murthy, M.K. (1988): Developments in Zirconia Toughened Alumina. Can. Ceram. Quart. 61(1), 14.

Kuriakose, A.K., Wheat, T.A., Ahmad, A. & Aota, J. (1988): The Effect of Precursor Raw Materials on the Tetragonal Zirconia Content of Alumina-Zirconia Ceramics. Can. Ceram. Quart., 61(1), 20.

Canaday, J.D., Kuriakose, A.K., Wheat, T.A. & Ahmad, A. (1988): Measurements of the Platinum/Hydronium-Nasicon System Can. Ceram. Quart. 61(1), 20.

Ahmad, A., Wheat, T.A., Kuriakose, A.K. & Quon, D.H.H. (1988): Effect of Processing Parameters on the Properties of Modified Lead Titanate. Can. Ceram. Quart. 61(1), 21.

Aota, J., Quon, D.H.H., Wang, S.S.B., Wheat, T.A., Kuriakose, A.K. & Torrie, G. (1989): Hydrothermal Synthesis of Zirconia and Preparation of Zirconia-Mullite Composites. Can. Ceram. Quart. 58, 25.

Chehab, S., Canaday, J.D., Kuriakose, A.K. & Wheat, T. A. (1989): A Hydrogen Sensor Using a Bonded Hydronium -Nasicon Solid Electrolyte. Can. Ceram. Quart. Feb., 32.

PATENTS:

Kuriakose, A.K., Wheat, T.A., Ahmad, A., Canaday, J.D. & Hanson, A.J. (1988): Bonded Hydrogen Conducting Solid Electrolytes. U.S. Pat. 4,724,191.

ORAL PRESENTATIONS - INTERNATIONAL:

Gulens, J., Longhurst, T.H., Kuriakose, A.K. & Canaday, J.D. (1987): Hydrogen Electrolysis using a Nasicon Solid Protonic Conductor. 6th International Meeting on Solid State Ionics, Garmisch-Partenkirchen, Germany.

Canaday, J.D., Kuriakose, A.K., Wheat, T.A., Ahmad, A., Gulens, J. & Hildebrandt, B.W. (1988): Bonded Solid Protonic Conductor/Platinum Electrochemical Cells. Meeting on Solid State Protonic Conductors IV, Exeter, U.K.

Gulens, J., Hildebrandt, B.W., Canaday, J.D., Kuriakose, A.K., Wheat, T.A. & Ahmad, A. (1988): Influence of Water on the Electrochemical Response of a Bonded Nasicon Protonic Conductor. Solid State Protonic Conductors IV, Exeter, U.K.

Wang, S.S.B., Quon, D.H.H., Aota, J. & Kuriakose, A.K. (1989): Degradation of Magnesia Carbon Bricks in Argon at High Temperature. Presentation at UNITECR at Anaheim Cal.

Lee, J., McMahon, G., Pant, A., Saleem, M., Sood, R., Kuriakose, A.K., Balbaa, I., DaRosa, V. & Klieb, J. (1989): Microwave Calcination of Gibbsitic Material. Am. Ceram. Soc. 91st. Annual Meeting, Indianapolis.

ORAL PRESENTATIONS - CANADA:

Kuriakose, A.K., Wheat, T.A., Ahmad, A. & Canaday, J.D. (1985): Spray-Dried Sodium-Potassium Beta/Beta"-Alumina. Annual Meeting of the Can. Ceram. Soc., Ottawa.

Ahmad, A., Wheat, T.A., Canaday, J.D. & Kuriakose, A.K. (1985): Electrical Characterization of Nasicon Ceramics. Annual Meeting of the Can. Ceram. Soc. Ottawa.

Wheat, T.A., Ahmad, A., Canaday, J.D. & Kuriakose, A.K. (1985): Hydrogen Conducting Solids. Can. Ceram. Soc. Annual Meeting, Ottawa.

Canaday, J.D., Ahmad, A., Kuriakose, A.K. & Wheat, T.A. (1985): Polarization Models for Protonically Conducting Electrolyte Fuel Cells. Annual Meeting of the Can. Ceram. Soc., Ottawa.

Canaday, J.D., Wheat, T.A., Kuriakose, A.K. & Ahmad, A. (1985): A Micro-computer System for Fuel Cell Experiments. The Electrochem. Soc., Spring Meeting, Toronto.

Wheat, T.A., Ahmad, A., Canaday, J.D. & Kuriakose, A.K. (1985): Advanced Ceramic Research Functions of CANMET. Industrial Seminar on Advanced Ceramics, Invited Poster Presentation; Queen's University.

Kuriakose, A.K., Wheat, T.A., Ahmad, A. & Canaday, J.D. (1986): Some Properties of Hydronium Zirpsios. Annual Meeting of the Can. Ceram. Soc., Toronto.

Canaday, J.D., Kuriakose, A.K., Ahmad, A. & Wheat, T.A. (1986): Electrical Measurements on Protonic Solid Electrolyte Cells. Annual Meeting of the Can. Ceram. Soc., Toronto.

Kuriakose, A.K., Wheat, T.A. and Hanson, A.J. (1987): Synthesis of Silicon Carbide. Annual Meeting of the Can. Ceram. Soc., Montreal.

Ahmad, A., Kuriakose, A.K., Wheat, T.A. & Canaday, J.D. (1987): Physical Characteristics of Na and Na-K Beta/Beta"- Aluminas. Can. Cer. Soc. Annual Meeting, Montreal.

Canaday, J.D., Kuriakose, A.K., Wheat, T.A. & Ahmad, A. (1987): Electrochemical Aspects of Protonic Solid Electrolyte Cells. Can. Ceram. Soc. Annual Meeting, Montreal.

Kuriakose, A.K., Wheat, T.A., Ahmad, A. & Aota, J. (1988): The Effect of Precursor Raw Materials on the Tetragonal Zirconia Content of Alumina-Zirconia Ceramics. Can. Ceram. Soc. Annual Meeting, Toronto.

Ghosh, D., Jacobs, J., Das Gupta, S., Wheat, T.A., Kuriakose, A.K. & Murthy, M.K. (1988): Developments in Zirconia-Toughened Alumina. Can. Ceram. Soc. Annual Meeting, Toronto.

Canaday, J.D., Kuriakose, A.K., Wheat, T.A. & Ahmad, A. (1988): Measurements on the Platinum/Hydronium-Nasicon System. Can. Ceram. Soc. Annual Meeting, Toronto.

Ahmad, A., Wheat, T.A., Kuriakose, A.K. & Quon, D.H.H. (1988): Effect of Processing Parameters on the Properties of Modified Lead Titanate. Can. Ceram. Soc. Annual Meeting, Toronto.

CANMET PUBLICATIONS:

Canaday, J.D., Kuriakose, A.K., Ahmad, A. & Wheat, T.A. (1986): An Electrochemical Analysis of Solid Electrolyte/Electrode Systems. CANMET Report 86-8E

CANMET DIVISIONAL REPORTS:

There are 22 MSL Divisional Reports from 1985 to September 1989. Three of them are listed below as examples.

Kuriakose, A.K., Wheat, T.A., Ahmad, A., & Canaday, J.D. (1985): A New Method for the Fabrication of Polycrystalline Hydrogen-Conducting Solid Electrolytes. CANMET Div. Rept. ERP/MSL 85-149 (IR).

Kuriakose, A.K. & Quon, D.H.H. (1986): Extrusion and Induration of Carol Lake Ore using Polymers and Calcium Carbonate for Bonding. CANMET Div. Rept. MSL 86-135 (IR).

Kuriakose, A.K., Wheat, T.A. Quon, D.H.H. & Ahmad, A. (1987): Preparation of Zirconia-Toughened Alumina. CANMET Div. Rept. MSL 87-151 (IR).

PARTICIPATION IN NATIONAL/INTERNATIONAL MEETINGS (other than oral presentations):

1987-1988:	Editor-in-chief, J. Can. Ceram. Soc.
1986-1987:	Associate Editor, J. Can. Ceram. Soc.
1983-1985:	Chairman, Ceramographic Committee of the Canadian Ceramic Society.
1982-1988:	Director, Canadian Ceramic Society.
1986-1987:	Session Chairman, Annual Meetings of Canadian Ceramic Society.
1989	Judge, Ceramographic Competition of the Canadian Ceramic Society.

CURRICULUM VITAE

NAME: T.A. Wheat

DEGREES: Ph.D (Ceramics), B.Sc (Chemistry), Leeds University

EXPERTISE:

Ceramic synthesis, processing and evaluation.

<u>CAREER:</u>	1988-Present	Research Scientist 4, CANMET (R&D: Ceramics)
	1986-Present	Section Head, CANMET (R&D: Ceramics)
	1979-1988	Research Scientist 3, CANMET (R&D: Ceramics)
	1973-1979	Research Scientist 2, CANMET (R&D: Ceramics)
	1968-1973	Research Scientist 1, CANMET (R&D: Ceramics)
	1966-1968	Post Doct. Fellow, UKAEA, Harwell (R&D: Ceramics)

PROFESSIONAL AFFILIATIONS:

Member	American, British and Canadian Ceramic Societies
Canadian Ceramic Society:	
President	1982
Director of The Board	1976-1986
Associate Editor of the Journal	1979-1983
Chairman of Publications Committee	1983
Chairman	1976
Secretary	1975 Electronics & Basic Science (EBS) Divn
Founding Chairman	1976-1979, Ceramographic Competition
Director	1975-present - EBS Division
Member	Panel of Fellows (1987-1990)

AWARDS:

1. Inventors Award, Can. Patents and Developments Ltd., (1989),
2. Silver Medal, Canada Awards for Excellence (1986),
3. Fellow, Canadian Ceramics Society (1985),
4. Inventors Award, Can. Patents and Developments Ltd., (1985).

CURRENT RESEARCH & OTHER ACTIVITIES:

Principal technical responsibility is the direction of a group of 13 full-time staff and four visiting staff dedicated to a wide range of joint projects with industrial partners. The areas of technical activity covered by the group include the following:

- (a) Sodium Conductors
- (b) Hydrogen Conductors
- (c) Piezoelectrics
- (d) Pyroelectrics
- (e) Surface Toughening
- (f) Applications of Statistical Design
- (g) Wear-resistant Materials
- (h) Silicon Carbide
- (i) Slip-casting, Hydrothermal Processing, Injection Moulding
- (j) Mechanical, Electrical and Thermal Properties
- (k) Refractories Evaluations, Failure Analysis
- (l) Consultations to Industry (C-Cubed)

As a result, the time is divided in the following manner:

50% Business Development: promotion of lab. capabilities, development of joint programs, promotion of C-Cubed, preparation and presentation of proposals to clients;

30% Administrative Affairs: preparation of annual and other reports, preparation, presentation and defence of programs to MNACC/TAG committees, provision of assessments and reviews for EMR and other agencies [NRC (IRAP, PRAI), ISTC (TOP-AIM, DIPP, IMDE), EA (TIP), EMR (RAP, IERD), DND (DIR), NSERC reviews and site visits]

20% Directing the research of others in the group in the areas above;

0% Conducting research directly.

SIGNIFICANT CONTRIBUTIONS:**1. Piezoelectric Materials**

Extensive work has been conducted in the field of piezoelectric materials by EMR and, later, their collaborators. As a result of that work and its transfer to the private sector, three companies now exist that employ over 100 full time staff producing these materials with over 70% of production going to export.

2. Solid Electrolytes

Programs have been in place since 1976 for the study and exploitation of a variety of solid electrolytes for use in energy and environmental control systems. The essence of the work is to verify (or otherwise) the claims made in the literature for the performance of materials and to exploit those found appropriate.

This has led to the pursuit of materials such as the zirconias, delta-bismuth oxide and the beta"-aluminas and the abandonment of several apparently attractive materials such as:

- the lithium zinc germanates (Lisicons) because of their exceptional sensitivity to water
- the sodium zirco-silico-phosphates (Nasicons) because of their instability to liquid sodium. This group of materials was heralded as the successor to the beta-aluminas as sodium-ion conductors because they are easier to produce and have a higher isotropic conductivity. CANMET demonstrated and explained why the Nasicons are unstable to both water and also liquid sodium - an observation that was latter corroborated by Ford, Dearborn.

In all, 12 systems have been examined: the most developed remains the beta"-aluminas, the technology for which has been transferred to Almax Industries Ltd. and demonstrated in a thermo-electric generator having no moving parts and an efficiency of 16-18% (compared with existing thermopiles that are 2-10% efficient). Currently, Powerplex Technologies Inc., (Divn of Magna International) has in place a \$12M program to produce Na-S batteries (that also exploit beta"-alumina) for electric vehicles. Presently, a number of battery-powered Chrysler Caravans are operating in Toronto. The program is conducted in collaboration with Brown Boveri & Co., Germany and NaSTech, Japan.

3. Hydrogen-conducting Solid Electrolyte - 'Hyceram'

As a spin-off of the solid electrolytes work above that focussed on O^{2-} , Na^+ , K^+ and Li^+ conductors, work was initiated under contract in 1980 to develop a hydrogen-conducting solid electrolyte. The initial work resulted in a joint patent with members of McMaster University. However, the strength of the material was abnormally low due to the severe internal damage incurred in ion-exchanging an initially strong sintered disc. Consequently, a different route was taken in EMR: ion exchange the precursor material in powder form first and bond the material together with a second phase. This led to the second patent and the establishment of 'Hyceram' as a CANMET Trademark for these materials.

Samples of these materials are being supplied for evaluation by labs in Germany, the U.K., ... and a joint program is underway with Nova Analytical Systems to exploit these materials in a hydrogen sensor that covers the range 0.1 to 100% to monitor the off gases from steel processing.

As a result of the work with these dielectric materials and the successful transfer of the technology to industry, CANMET was awarded the Silver Medal in Technology Transfer in the 1986 Canada Awards for Excellence.

4. Zirconia-toughened Alumina and Mullite

Wear resistant ceramics have been projected by many to have a growing market. Applications include service at both ambient and elevated temperatures. The former can well exploit the zirconia-toughened systems whereas the latter usually depend on the non-oxides and their composites.

The essence of this work is the development of materials having nearly three-times the wear resistance and four-times the impact resistance for a cost increase of approximately 30% over the base material. The program has focussed on both ZrO_2 -toughened alumina and mullite.

5. Development of Silicon Carbide of Controlled Morphology

The objective is to understand and optimize the processes that yield sub-micrometre beta silicon carbide in various forms and morphologies, their characterization and final fabrication into sintered monoliths. So far, progress includes the development of sub-micrometre single-phase β silicon carbide powder on a lab scale and the identification of the mechanisms and processes that operate in the control and growth of material with a specific morphology (equiaxed powders, plates or fibres).

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ANALYTICAL STANDARDS AND METHODS



CURRICULUM VITAE

NAME: Elsie M. Donaldson

DEGREES: B.Sc. (Honours Chemistry), 1951,
University of Manitoba

EXPERTISE:

Thirty-eight years of experience in analytical methods development, solvent extraction and separation techniques based on co-precipitation, volatilization and electrodeposition, as applied to the determination of small and trace amounts of diverse elements in mineralogical and metallurgical materials by instrumental techniques such as flame photometry, light-absorption spectrophotometry, and flame, graphite-furnace and hydride-generation atomic-absorption spectrometry. This also includes expertise in classical "wet-chemical" analysis of ores, rocks and related materials.

<u>CAREER:</u>	1982-present	Research Scientist 3, CANMET
	1965-1982	Research Scientist 2, CANMET
	1964-1965	Senior Scientific Officer 1, Mines Branch
	1954-1964	Scientific Officer 1 to 3, Mines Branch
	1951-1954	Chemist 1 and 2, Mines Branch

PROFESSIONAL AFFILIATIONS:

Member of the Chemical Institute of Canada
Member of the Spectroscopy Society of Canada
Member of the Advisory Board of Talanta

CURRENT RESEARCH AND OTHER ACTIVITIES:

- (a) Development of methods for the determination of trace amounts of diverse elements in ores, concentrates and related materials by hydride-generation (HGAAS) or graphite-furnace atomic-absorption spectrometry (GFAAS) (80% of time).

- (1) Research work has just been completed on the determination of antimony in these materials by HGAAS after separation from the matrix elements by xanthate extraction.
 - (2) Future research work will involve the development of methods for the determination of trace amounts of gold and the platinum-group elements by either deuterium-arc or Zeeman corrected GFAAS.
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- (b) Administrative activities - as a Chemical Laboratory Section Head include planning the approaches for the research and other related activities of a junior Chemist within the section, and general administrative activities such as employee evaluation and supervision (5% of time).
 - (c) Refereeing of papers for chemical journals and for in-house and other scientific personnel, and analytical consultation (5% of time).
 - (d) Duties as a member of the Analytical Working Group of the Copper Refiners Group (5% of time).
 - (e) Project planning and review - as coordinator for the Chemical Laboratory contribution to the Mineral Sciences Laboratories annual report, and occasionally for other Chemical Laboratory activities or required documentation (2.5% of time).
 - (f) Health and safety associated with chemicals and organic solvents (2.5% of time).

SIGNIFICANT CONTRIBUTIONS:

1. A study of the methyl isobutyl ketone extraction of 15 elements as iodides from sulphuric acid-potassium iodide media has contributed significantly to a better understanding of the extraction behaviour of these complexes and has resulted in the development of a method for the simultaneous extraction and determination of small amounts of silver, antimony, copper, cadmium, bismuth and indium in ores and related materials by flame atomic-absorption spectrometry (AAS). This method has been very useful for the high-precision analysis of candidate reference materials produced by CANMET's Canadian Certified Reference Materials Project (CCRMP).
2. Methods involving the separation of analyte elements by extraction of their xanthate complexes have been developed for the determination of trace amounts of arsenic by both graphite-furnace and hydride-generation AAS, for tellurium

by graphite-furnace AAS, and for the simultaneous extraction and determination of small amounts of cobalt, nickel, lead, bismuth and indium by flame AAS. These investigations have contributed significantly to the field of solvent extraction of xanthate complexes and have demonstrated the usefulness of this separation technique in solving many analytical problems arising from matrix interferences.

Because of the ever-increasing demand for reference ores, concentrates and related materials with certified trace element contents, these methods, as well as a graphite-furnace method for determining ng-amounts of selenium in these materials, have been extremely useful for CCRMP work and for the analysis of products arising from other CANMET research projects. Many requests are received for these methods attesting to their usefulness to other researchers and technical workers.

3. Recent work involving a study of the sources of error in the determination of nickel in copper anodes and copper anode slimes (in-house report), which was carried out as a participating member of the Analytical Working Group of the Copper Refiners Group, showed that the discrepancies in the nickel values obtained during a round-robin study were caused by incomplete decomposition of nickel oxides. Methods for the accurate AAS determination of nickel in these materials were suggested and used by participants in subsequent collaborative work. Accuracy in the determination of nickel in these materials is very important in the copper industry in understanding its behaviour during the electrorefining of copper.
4. As a member of the Advisory Board of, and a long-time contributor to, *Talanta*, an international chemical journal, 21 papers and 2 books dealing with analytical chemistry in the mining industry were reviewed for this journal since 1985. Six other papers were reviewed for CANMET Chemical Laboratory and Geographical Survey of Canada personnel, and several reports for inclusion in the International Atomic Energy Agency uranium industry laboratory manual and numerous in-house reports were technically edited. A chapter on classical wet chemical analysis was also technically reviewed for the American Society for Testing and Materials for inclusion in their handbook entitled "Metals Handbook: Materials Characterization". Consultation and advice on problem-solving in analytical methodology is also prescribed both in-house and on a national and international basis. Advice was also sought by the CRC Press in Boca Raton, Florida on the timeliness of the subject material and the qualifications of a member of the Geological Institute in

Prague for writing a book on decomposition methods in inorganic chemistry.

REFEREED JOURNAL ARTICLES:

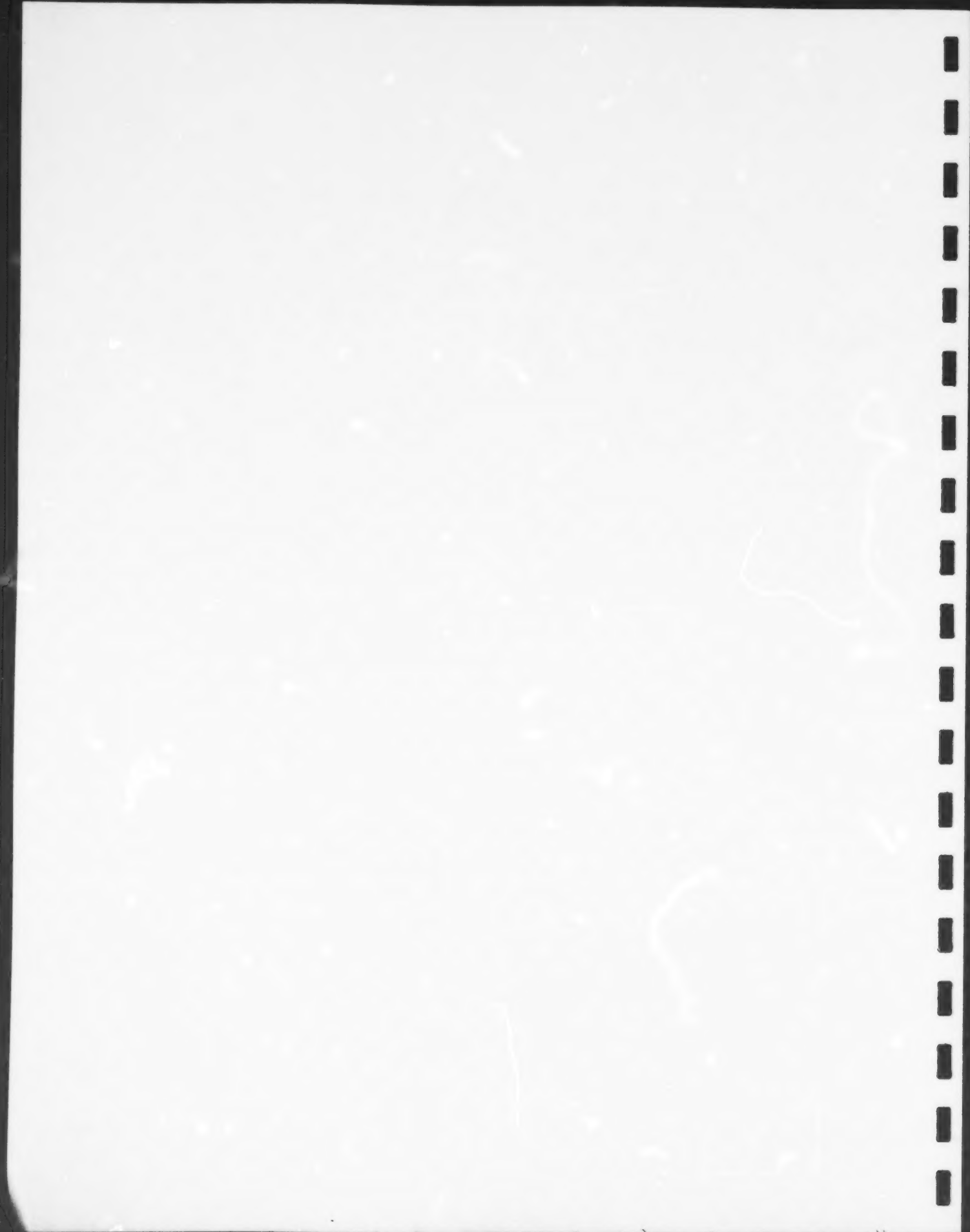
- Donaldson, E.M. and Wang, M. (1986): Methyl isobutyl ketone extraction of iodide complexes from sulphuric acid-potassium iodide media and back-extraction into an aqueous phase. *Talanta* 33, 35-44.
- Donaldson, E.M. and Wang, M. (1986): Determination of silver, antimony, bismuth, copper, cadmium and indium in ores, concentrates and related materials by atomic-absorption spectrophotometry after methyl isobutyl ketone extraction as iodides. *Talanta* 33, 233-242.
- Donaldson, E.M. (1988): Determination of arsenic in ores, concentrates and related materials by graphite-furnace atomic-absorption spectrometry after separation by xanthate extraction. *Talanta* 35, 47-53.
- Donaldson, E.M. and Leaver, M.E. (1988): Determination of arsenic in ores, concentrates and related materials by continuous hydride-generation atomic-absorption spectrometry after separation by xanthate extraction. *Talanta* 35, 297-300.
- Donaldson, E.M. (1988): Determination of selenium in ores, concentrates and related materials by graphite-furnace atomic-absorption spectrometry after separation by extraction of the 4-nitro-o-phenylenediamine complex. *Talanta* 35, 633-639.
- Donaldson, E.M. (1989): Determination of cobalt, nickel, lead, bismuth and indium in ores, soils and related materials by atomic-absorption spectrometry after separation by xanthate extraction. *Talanta* 36, 543-548.
- Donaldson, E.M. and Leaver, M.E. (1989): Determination of tellurium in ores, concentrates and related materials by graphite-furnace atomic-absorption spectrometry after separation by iron collection and xanthate extraction. *Talanta*, in press.

BOOK REVIEWS:

- Donaldson, E.M., "Analytical Chemistry in the Exploration, Mining and Processing of Materials", L.R.P. Butler (Editor); Blackwell Scientific Publications, 254 pages; Oxford, England; 1986; review in *Talanta* 35:i; 1988.

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Donaldson, E.M., "Assay and Analytical Practice in the South African Mining Industry"; W.C. Lenahan and R. de L. Murray-Smith; South African Institute of Mining and Metallurgy, 640 pages; Johannesburg, South Africa; 1986; review in Talanta 35:i; 1988.



CURRICULUM VITAE

NAME: Robert Sutarno, PhD, P. Eng.

DEGREES: Ph.D. 1965, Technical University of Nova Scotia
 M.E. (Chem. Eng.) 1963, Technical University of Nova Scotia
 B.E. (Chem. Eng.) 1960, Technical University of Nova Scotia

EXPERTISE:

Application of statistical methods in mining and mineral processing industries in bulk sampling of and to the accuracy of measurement methods as applied to the chemical and physical analyses of iron ores and base metal concentrates.

Application of statistical methods to process quality control, nuclear materials inventory control, reference materials, laboratory certification, specifications, laboratory quality control, sampling of mine dust, etc.

Five years research on hard ferrite materials (magnetic ceramic materials) (1965 - 1970)

<u>CAREER:</u>	1980 - present	Research Scientist 3, CANMET
	1970 - 1980	Research Scientist 2, CANMET
	1967 - 1970	Research Scientist 1, Mines Branch
	1965 - 1967	Scientific Officer 3, Mines Branch
	1960	Chemical Engineer, Polymer Corp.

PROFESSIONAL AFFILIATIONS:

1. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

1.a. ISO/TC 102 - (Iron ores):

- Past chairman of the Canadian Advisory Committee (CAC) on Sampling Subcommittee (SC) (1976-1986).
- International Convener of ISO/TC 102/SC 2/WG 12 (Chemical Analysis Subcommittee - Working Group on Evaluation of Statistical Data) (1974-present).

1.b. ISO/TC 183 - (Copper, lead and zinc ores and concentrates):

- International Convener of ISO/TC 183/WG 10 (Working Group on Statistical Evaluation of Test Programs) (1986-present).

1.c. ISO/TC 69 - (Application of statistical methods):

- Chairman of the CAC/ISO/TC 69/SC 6 (Measurement Methods and Results (1986-present).
- International Convener of ISO/TC 69/SC 6/WG 4 (Statistical Aspects of Reference Materials) (1984-present).

1.d. ISO/REMCO:

- Member of the CAC/ISO/REMCO (1980-present).

2. AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

- Executive member of Committee E-16 (1986-1988).

3. CANADA

3.a. Canadian Standards Association (CSA)

- Member of CSA Committee on Application of Statistical Methods.

3.b. Member of Association of Professional Engineers of Ontario (APEO)

AWARDS:

Recipient of "John L. Hague" award, in recognition for significant technical contribution to the initiation, preparation or development of E-16 standards for testing ores. This award was presented by the American Society for Testing and Materials (ASTM) Committee E-16.

CURRENT RESEARCH AND OTHER ACTIVITIES:

- (a) ISO/TC 183 (Copper, lead and zinc ores and concentrates) (30% of time)

Standardization in the field of copper, lead and zinc ores and concentrates, including sampling, chemical analysis and physical testing.

As convener of ISO/TC 183/WG 10

To serve as the central data processing agent for the TC:

1. To design the experiment and to statistically evaluate all analytical data resulting from international tests conducted by ISO/TC 183. The results of this evaluation are used as one of the bases for the acceptability of the analytical method for adoption as an international standard.
2. To design, operate and maintain data bases for the technical committee.

Five international tests for the determination of suitability of various methods for analysis of copper, lead and zinc concentrates as ISO standards are being conducted by ISO/TC 183 during the period of 1989/1990.

Collaborating organizations:

Canada: Mines Noranda Limitee, Hudson Bay Mining & Smelting Co. Ltd., Matrix Consultants Ltd., Cominco Ltd., Kidd Creek Mines Ltd., Canadian Electrolytic Zinc Ltd. and Afton Operating Corp.

International: Laboratories from Australia, Belgium, China, France, Germany, Finland, Japan, Papua, New Guinea, Philippines, Spain, UK, USA and USSR.

(b) ISO/TC 102 (iron ores) (30%)

Standardization in the field of iron ores, including terminology, methods of sampling, preparation of samples, methods for the determination of size and classification of size, methods for the determination of moisture content, methods for chemical analysis and methods for physical testing.

1. As convener of ISO/TC 102/SC 2/WG 12

To provide the same service as in (I) above for ISO/TC 102 (iron ores). Four international tests for the determination of suitability of various methods for analysis of iron as ISO standards are being conducted by ISO/TC 102/SC 2 during the period of 1989/1990.

2. To participate in the activity of ISO/TC 102/SC 1 (Iron ores - sampling)

To provide expertise and continuity for the CAC on iron ores sampling. Sampling experiments are being conducted by various companies and the results will be evaluated by CANMET for submission as Canadian contribution to ISO effort.

3. To participate in the activity of ISO/TC 102/SC 3 (Iron ores - Physical testing) and SC 5 (Direct reduced iron)

To collaborate in the experiments for the determination of sampling parameters for physical testings of iron ores and sampling for direct reduced iron.

Collaborating organizations:

Canada: Iron Ore Company of Canada, Quebec Cartier Mining, Sidbec-Dosco, Dofasco, Stelco, Matrix consultants Ltd., George W. Riley & Associates and Centre de Recherches Minerales.

International: Laboratories from Australia, Brazil, France, Germany, Japan, Netherlands and USSR.

- (c) ISO/REMCO (ISO Committee on Reference Materials) (10%)

To serve as convener of joint working group between ISO/REMCO and ISO/TC 69 to develop methods for application of reference materials for calibration purposes.

- (d) ISO/TC 69 (Applications of Statistical Methods) (15%)

1. To participate in the development of ISO 5725: "Accuracy (trueness and precision) of measurement methods and results". This standard is a generic standard for use by all ISO technical committees. It contains methods both for measurement and for application of accuracy parameters of test methods. To harmonize this standard with those used by other international organizations namely IUPAC and AOAC (Association of Official Analytical Chemists - USA).

2. To participate in the hosting committee for international meeting of ISO/TC 69 to be held in Ottawa, Canada, July 1990.

Collaborating organizations: Members of ISO/REMCO and ISO/TC 69/SC 6

- (e) Administrative and continuing education: (15%) Miscellaneous administrative duties and courses such as computer course, French course etc.

SIGNIFICANT CONTRIBUTIONS:

1. Developed experimental design used by ISO/TC 183 (Copper, Lead and Zinc ores and concentrates), statistically evaluated all the analytical data resulting from international tests conducted by the technical committee and used the results of evaluations for the basis of the acceptability of the analytical methods as international standards. Set up data base to permanently maintain these data for future use by the technical committee.
2. The same as (1) above used by ISO/TC 102/SC 2 (Iron ores - Chemical analysis).
3. Co-author of ISO Guide 35 "Certification of reference materials - General and statistical principles" and ISO Guide 33 on "Uses of certified reference materials"
4. Major contributor to ISO 5725: Accuracy (trueness and precision) of measurement methods and results". A generic standard for use by all ISO technical committees.
5. As convener of ISO/TC 69/SC 6/WG 4 played an important part in changing the scope of statistical methodology within ISO technical committees from concern about "precision" to concern about "accuracy (trueness and precision)" of measurement methods.

REFEREED JOURNAL ARTICLES:

- Sutarno, R. and Steger, H.F. (1985), "Validation of accuracy by interlaboratory program", Talanta, Vol 32, No. 11, pp 1088-1091.
- Steger, H.F. and Sutarno, R. (1986), "Stability of CRM's: Significance to the user", MRP/MSL 85-127 (J). Geostandards Newsletter, Vol 10, No. 1, pp 93-98.
- ISO Guide 33 (1989) "Uses of reference materials", International Organization for Standardization, Case postale 56, CH-1211 Geneva 20, Switzerland.

ISO Guide 35 (1989) "Certification of reference materials - General and statistical principles", International Organization for Standardization, Case postale 56, CH-1211 Geneva 20, Switzerland.

DIVISIONAL REPORTS:

42 REPORTS, most of which were circulated to the respective ISO technical committee members as ISO working documents. For example, the following reports represent these Technical Committee working documents.

Sutarno, R. and Bowman, W.S. (1986), "Iron Ores - Redoximetry Determination of Total Iron - Mercury Pollution Free Methods - Statistical Evaluation of International Test Data - 1984", MRP/MSL 85-42 (IR).

Sutarno, R. (1987), "ISO/DP 5725 Part 4 - Basic method for estimating the trueness of a test method", MSL 87-130 (J).

Sutarno, R. and Bowman, W.S. (1988), "ISO/TC 183/WG 2A Determination of gold and silver in copper concentrates by fire assay - AAS/titration method - Statistical evaluation of international test data 1986-1988", MSL 88 - 26 (OP & J).

PARTICIPATION IN NATIONAL/INTERNATIONAL MEETINGS (other than oral presentations):

Served as Canadian delegate, and/or convener at 20 various meetings of ISO/TC 69, ISO/TC 102, ISO/TC 183 and ISO/REMCO.

CURRICULUM VITAE

NAME: H.F. Steger

DEGREES: BSc., 1965, McMaster University
PhD., 1969, McMaster University

EXPERTISE:

Research chemist in inorganic metal complex chemistry, base metals adsorption by clays and ambient oxidation of sulphide minerals. Expertise in the development of analytical methods. Experience in experimental design in the study of the geochemistry of and the coordination of the development of a model for the simulation of acid generation in mineral process tailings. Expertise in the certification of reference materials and development of practical concepts and statistical design for the use of these materials in the analytical laboratory. Currently, Manager of the Chemical Laboratory of the Mineral Sciences Laboratories of CANMET.

<u>CAREER:</u>	1986-present	Manager, Chemical Laboratory, CANMET
	1976-1986	Research Scientist 2, CANMET
	1969-1976	Research Scientist 1, CANMET

PROFESSIONAL AFFILIATIONS:

Member of the Canadian Chemical Institute
Chairman of the Canadian Advisory Committee to the Council Committee on Reference Materials, REMCO, to the International Organization for Standardization, ISO

CURRENT RESEARCH & OTHER ACTIVITIES:

As a member of the Modelling Sub-committee of the CANMET MEND Program, to oversee, under CANMET contract, a critical review of the base metal tailings computer model, RATAP, and to participate in an international workshop to review and compare RATAP against other models or partial model modules available for the same purpose. (10% of time)

To coordinate an interlaboratory analytical program to certify three pyrometallurgical reference materials for sulphur to ensure high accuracy and precision in the analyses of the feed stream materials of the pyrometallurgical industry. These analyses are widely used to calculate with reasonable accuracy the quantity of sulphur dioxide emissions. This study also includes a comparison of the current analytical methodology for

sulphur and an in-depth assessment of the barium sulphate precipitation procedure. (10%)

To continue as Chairperson of CAC/ISO/REMCO and to serve as Canadian representative to ISO/REMCO in the development of standards for reference materials. (5% of time)

SIGNIFICANT CONTRIBUTIONS:

1. Certified Reference Materials

Participated in the formulation of guidelines for (i) the certification of reference materials and (ii) the use of reference materials for the assessment of the accuracy and precision of analytical data and methods and for the calibration of instruments. The latter were the first to be openly published. These efforts were also the Canadian contributions to the Council Committee on Reference Materials of the International Organization for Standardization (ISO/REMCO) and comprise major portions of ISO/REMCO Guides 33 and 35 published for international distribution.

2. Geochemistry and Modelling of Mineral Tailings

Oversaw, through CANMET contracts, the development of a computer model, RATAP, to simulate the oxidation of pyrite in uranium mill tailings in order to estimate the generation of acid and the transport of ionic species over the long term. Was responsible for the adaptation and expansion of this model to base metal mill tailings by taking into consideration other sulphide minerals and additional toxic elements such as arsenic.

REFEREED JOURNAL ARTICLES:

Sutarno, R. & Steger H.F. (1985): The use of certified reference materials in the verification of analytical data and methods. Talanta 32, 439-445.

Steger, H.F., Bowman, W.S. & McKeague, J.A. (1985): Additional certified values for CCRMP soils SO-1 to SO-4. Geostandards Newsletter 9, 213-218.

Steger, H.F. & Smith, C.W. (1985): Recommended lead-210 values for four CCRMP uranium reference ores. Geostandards Newsletter 9, 229-231.

Steger, H.F. (1985): Effect of EDTA/NaF solutions on the Orion Cu(II) ion selective electrode. Talanta 32, 235-237.

Sutarno. R. & Steger, H.F. (1985): Validation of accuracy by interlaboratory program. Talanta 32,1089-1091.

Steger, H.F. & Sutarno, R. (1986): Stability of CRM's: significance to the user. Geostandards Newsletter 10, 93-98.

Steger, H.F. & Legeyt, M. (1987): Radium-226 in uranium mill tailings I. fate and consequent dissolution. J. Radio. Nucl. Chem. 111, 95-104.

Sutarno, R. & Steger, H.F. (1988): The use of certified reference materials in the assessment of the accuracy and precision of measurement procedures. ISO/REMCO Guide 33.

Steger, H.F. (1988): Proper use and mis-use of reference materials. ISO/REMCO Guide 33.

OTHER CONFERENCE PROCEEDINGS:

Steger, H.F. (1988): Reference materials and special analysis for the precious metals. Proc. CANMET, Partner with the Quebec Mineral Industry (Gaetan, R. ed.), February.

Steger, H.F., Smith, C.W., Melis, L.A., Knapp, R.A. & Scharer, R. (1987): Study of the state of nickel and arsenic in uranium mill tailings. Proc. CIM International Symposium on Crystallization and Precipitation, Saskatoon, Saskatchewan. October 5-7.

Smith, C.W. and Steger, H.F. (1987): Canadian compositional reference materials for uranium and thorium decay series isotopes. 33rd Ann. Conf. Bioassay, Analytical & Environmental Radiochemistry, Berkeley, CA. Program Abstr., Paper 46.

ORAL PRESENTATIONS:

Steger, H.F. (1985): Update of the measurements project of NUTP", CANMET. Presented at the 3rd Workshop on Analytical Chemistry related to Canada's Nuclear Industry, October 22, Kimberley, Ontario.

Steger, H.F. & Legeyt, M. (1986): The dissolution of radium-226 in uranium mill tailings", MRP/MSL 86-68(OP). Presented at the Conference of the Chemical Institute of Canada, June 3, Saskatoon, Saskatchewan.

Steger, H.F. (1988): Quality control is like knowledge-a little bit can be a dangerous thing. Presented at the 4th Workshop on Analytical Chemistry related to Canada's Nuclear Industry, May 18, Kimberley, Ontario.

CANMET PUBLICATIONS:

Steger, H.F. & Bowman, W.S. (1985): CH-1 and CH-2: certified reference gold ores. CANMET Rep. 85-1E.

Steger, H.F. & Bowman, W.S. (1985): RL-1: a certified uranium reference ore. CANMET Rep. 85-4E.

Smith, C.W., Steger, H.F. & Bowman, W.S. (1986): MA-1a, MA-2a and MA-3: certified gold reference ores. CANMET Rep. 86-1E.

DIVISIONAL REPORTS:

Steger, H.F. (1985): The preparation of RGU-1 for I.A.E.A.", MRP/MSL 85-11(CR).

Smith, C.W., Grasty, R.L., Bowman, W.S. & Steger, H.F. (1987): The preparation for I.A.E.A. of RGTh-1, a thorium radiometric reference material", MRP/MSL 87-1(CR).

PARTICIPATION IN NATIONAL/INTERNATIONAL MEETINGS (other than oral presentations):

1985-1989: Chairperson of CAC/ISO/REMCO, Canadian Advisory Committee to Council Committee on Reference Materials of the International Organization for Standardization. Canadian delegate to international meetings of ISO/REMCO.

Steger, H.F. (1985): Delegation report - 11th meeting of REMCO, Geneva, Switzerland, December 11-13.

Steger, H.F. (1986): Delegation report - 12th meeting of REMCO, Geneva, Switzerland, October 15-17.

Steger, H.F. (1987): Delegation report - 13th meeting of REMCO, Geneva, Switzerland, October 7-9.

CURRICULUM VITAE

NAME: Michael G. Townsend

DEGREES: Ph.D. 1959, University of Southampton, UK
F. Inst. P. 1972, Institute of Physics, London, UK

EXPERTISE:

Expertise in solid-state physics and chemistry, chemical physics and in radiation including electrical, magnetic, optical, infra-red, fluorescent, magnetic resonance and Mössbauer properties of metals, insulators, semi-conductors, glasses, polymers, minerals, molecules; neutron scattering in minerals; cracking of bithumen tar sands; device physics; acoustic-spin wave interaction in solids; Radiation and Health and Safety of Miners. Magnetic separation for minerals beneficiation. Twenty one years at CANMET.

<u>CAREER:</u>	1975-present	Research Scientist 3, CANMET
	1985-1986	Professeur Associé, CENG, Grenoble, France
	1982-1983	Professeur Associé, CNRS, Grenoble, France
	Summer 1979	Senior Research Associate, AERE Harwell, UK
	Summer 1976	Visiting Scientist CNRS, Grenoble, France
	1973-1974	Senior Research Associate Nuclear Physics Division, AERE Harwell, UK
	1969-1975	Research Scientist 2, CANMET
	1962-1968	Research Officer, NV Philips, Eindhoven, The Netherlands and Redhill, Surrey, U.K.
	1958-1961	Research Associate, Washington University, St. Louis, MO, U.S.A.
	1970-1973	Part-Time Lecturer, University of Ottawa

PROFESSIONAL AFFILIATIONS:

Elected Fellow of the Institute of Physics, London, 1972

CURRENT RESEARCH AND OTHER ACTIVITIES:

- (a) Radiation: has recently prepared an article - CANMET and the Pylon 1000 - for GEOS November 1989. (15% of time)
- (b) Minerals Beneficiation: is developing further a mathematical model of a rotating eddy-current magnetic separator so as to improve its design and enable small particles of aluminum to be separated. (60% of time)
- (c) Acid Tailings: has begun examining computer model of acid leakage in mine tailings with a view eventually to produce a superior mathematical model. (15% of time)
- (d) Committee duties, including refereeing and reviewing manuscripts and grant proposals. (10% of time)

SIGNIFICANT CONTRIBUTIONS:

1. Radiation

Served as consultant at NEA, OECD Paris, to the International Group of Experts committee on Methodology and Monitoring of Radon, Thoron and their Daughters; a book was written and published in 1985 by the Group. Acted as Scientific Authority for some 9 contracts given by EMR to industry during this period.

2. Solid State Physics

Involved, jointly with the Metals Technology Laboratories, with amorphous metallic alloys and their possible applications as magnetic field and stress sensors for Canadian industry.

3. Magnetic Separator

Developed a mathematical model to establish the effects of important parameters in order to improve the design for a rotating eddy-current magnetic separator produced under cost-recovery to Alcan for separation of aluminum from cryolite.

REFEREED JOURNAL ARTICLES:

- Townsend, M.G. (1989). CANMET and the Pylon-1000. GEOS.
- Ryan, D.H., Strom-Olsen, J.O. (McGill University), Provencher, R. and Townsend, M.G. (1988). Transverse spin freezing in $Y.Fe_{92}Zr_8$. Journal of Applied Physics 64 5787-5791.
- Provencher, R., Brett, ME. and Townsend, M.G. (1987). Superconductivity and materials preparation in $YBa_2Cu_3O_{6+x}$ Physics. Stat. Solid. 103 K107-111.
- Townsend, M.G., Longworth, G. (AERE Harwell), Ross, C.A.M. (British Geological Survey) and Provencher, R. (1987). Ferromagnetic or antiferromagnetic Fe III spin configurations in sheet silicates. Phys Chem Minerals 15 64-70.
- Longworth, G. (AERE Harwell), Townsend, M.G., Provencher, R. and Kodama, H. (Agriculture Canada) (1987). Magnetic interaction in biotites and oxidised biotites. Phys Chem Minerals 15 71-77.
- Hogarth, D.D. (Ottawa U), Chao, G.Y. (Carleton U) and Townsend, M.G. (1987). Potassium and fluorine-rich amphibole from Gatineau, Quebec. Can Mineral 25 739-753.
- Townsend, M.G. (1986). Reply to "Comment on magnetism in biotites". Phys Chem Minerals 13 282-283.
- Townsend, M.G., Longworth, G. (AERE Harwell), and Roudaut, E. (CENG Grenoble) (1986). Triangular-spin Kagome plant in jarosites. Physical Review 33 4919-4926.
- Ballet, O. (CENG Grenoble), Coey, J.M.D. (Trinity College, Dublin), Mangin, P. ILL Grenoble) and Townsend, M.G. (1986). Ferrous talc a planar antiferromagnet. Solid State Communications.
- Townsend, M.G., Longworth, G. (AERE Harwell) and Kodama, H. (Agriculture Canada) (1986). Magnetic interaction at low temperature in chlorites and their oxidation products: a Mossbauer investigation. Can. Mineral 24 105-111.
- Longworth, G. (AERE Harwell), Townsend, M.G. and Ross, C.A.M. (British Geological Survey) (1986). Mossbauer spectra of several magnetic sheet silicates in external magnetic field. Hyperfine Interactions 28 451-454.
- Townsend, M.G., Longworth, G. (AERE Harwell) (1985). Sign of the magnetic coupling of Fe^{2+} and Fe^{3+} in biotite. Physics and Chemistry of Minerals 12.

Townsend, M.G., Longworth, G. (AERE Harwell) and Roudaut, R. (CENG Grenoble) (1985). Field-induced ferromagnetism in Minnesotaite. Physics and Chemistry of Minerals 12 9-12.

Townsend, M.G., Longworth, G. (AERE Harwell) and Dutrizac, J. (1985). Linear chain antiferromagnetism in FeOHSO_4 and FeOHCrO_4 . Physical Review 31B 2966-2973.

BOOKS:

Senior author of "Methodology and monitoring of radon, thoron and their daughters", published in 1985 by the Nuclear Energy Agency of the Organization for Economic Cooperation and Development, Paris.

ORAL PRESENTATIONS:

Townsend, M.G. Transverse spin freezing in $\text{Y-Fe}_{92}\text{Zr}_8$. Invited presentation at International Conference on Magnetism and Magnetic Materials, Vancouver, July 1988.

Townsend, M.G. (1987). Magnetism in sheet silicates. Dalhousie University, Halifax, Nova Scotia.

Townsend, M.G. (1986). Magnetism in sheet silicates. CENG, Grenoble.

Townsend, M.G. Triangular-spin Kagome plane in jarosites. Chemistry Department, Concordia University, Montreal, invited seminar, November 1985.

Townsend, M.G. (1985). Applications of magnetism in the minerals industry. Mineral Sciences Laboratories Seminar, June 1985.

Townsend, M.G. and Longworth, G. (AERE Harwell). Mossbauer spectra of several magnetic sheet-silicates in external magnetic field. Louvain, Belgium, International Conference on Applications of the Mossbauer Effect, September 1985.

Townsend, M.G. (1985). Neutron diffraction, Mossbauer, susceptibility and conductivity applied to magnetic problems. Physical Metallurgy Division Seminar, March 1985.

PARTICIPATION IN NATIONAL/INTERNATIONAL MEETINGS (other than oral presentations):

1985: Consultant to International Group of Experts on Methodology and Monitoring of Radon, Nuclear Energy Agency, Organization for Economic Cooperation and Development, Paris.

1985-1989: NSERC University-Industry Committee on Very Large Scale Integrated (VLSI) Circuits, to coordinate 3 million dollar grant to University of Toronto.